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Technical Workshop: Advanced Helicopter Cockpit Design Concepts

December 1984

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Sponsored by
Ames Helicopter/VTOL Human Factors Office
Aircraft Guidance and Navigation Branch
July 26-28, 1983

NASA
National Aeronautics and
Space Administration

NASA Conference Publication 2351

Technical Workshop: Advanced Helicopter Cockpit Design Concepts

Edited by John C. Hemingway and George P. Callas
Ames Research Center, Moffett Field, California

Sponsored by
Ames Helicopter/VTOL Human Factors Office
Aircraft Guidance and Navigation Branch
July 26-28, 1983

NASA
National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, California 94035

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PREFACE

Information processing demands on both civilian and military aircrews have increased enormously as rotorcraft have come to be used for adverse weather, day/night, remote area missions. Ironically, due to training costs and other manpower related factors, increasing pressure is also being exerted to reduce crew size. The Army has indicated considerable need for developing aircraft for the 1990's, and single-place concepts, such as being considered as an option for the LHX, are undergoing study in the DOD. Because of these conflicting trends, there is considerable debate over the need for fundamental changes in cockpit design philosophy, and the engineering guidelines needed for making such changes. On one hand, strong views have been expressed that current cockpits contain far more information than is really necessary. Hence, simplification to bare essentials is advocated. On the other hand, it is argued that systems have become so complex, and missions so demanding, that future cockpits must incorporate more machine intelligence, with increasingly sophisticated information transfer technology.

In response to the foregoing, NASA-Ames Research Center hosted a technical workshop on Advanced Helicopter Cockpit Design Concepts at Moffett Field, California on July 26-30, 1983. Stated objectives of the workshop included: (1) To identify applied psychology, engineering or operations research that should be conducted to develop future helicopter cockpit design criteria, and (2) To specifically identify rotary-wing research that should properly be supported by NASA.

The workshop addressed three areas: (1) Operational Requirements, (2) Advanced Avionics, and (3) Man-System Integration. The first day included formal presentations and committee assignments. The second day consisted of committee meetings, and the third day was devoted to Committee Reports and a "wrap-up". The first day's formal reports included:

Introductory Presentations - an overview of NASA-Ames and the Army's AMRL helicopter human factors and avionics crewstation integration efforts, including a description of the Superaugmented Rotorcraft New Initiative.

Operational Requirements - reports from selected Army, Marine, Coast Guard, Law Enforcement, and Civilian operators and project personnel on current and projected operational requirements for helicopters.

Advanced Avionics - presentations by project leaders on state-of-the-art avionics technology developments for the next generation of rotary-wing aircraft.

Man-System Integration - man-machine interface considerations and approaches for rotary-wing aircraft incorporating advanced technology including automation, artificial machine intelligence, display media, and variable task loading on operators.

The committee meetings from the second day's activities were presented when the workshop reconvened on the third day. Summary and Wrap-up reports suggested that avionics and human factors R&D efforts were proceeding along complementary lines for future perceived operational needs, but at unacceptably slow rates of progress for LHX program milestones. Research and technology requirements identified by all three committees reflected very similar needs to those described by the NASA-Ames Superaugmented Rotorcraft Program New Initiative.

This volume is a compilation of the proceedings from the individual presentations and committee reports. Because the workshop results have a broad spectrum of interest and the findings are critical to programs that are currently being formulated, the publication of this document has been expedited without critical review. The presentations and reports are transcribed in the form submitted by the respective authors. View graphs from some of the committee sessions are included without supporting text, however, in most instances the visuals are self-explanatory.

The chairmen are particularly grateful to the Center Director, Mr. Clarence Syvertson, for initiating the concept for the workshop and for his welcoming remarks. Also acknowledged is the assistance of the Session Chairmen, Dr. James W. Voorhees and Dr. Harry L. Snyder, Dr. John S. Bull and Mr. Richard B. Huntoon, and Dr. Roger W. Remington and Dr. Earl L. Wiener, as well as the individual presenters who devoted much time and effort to this workshop. Special notes of thanks are due Mr. Jerry S. Seeman, who chaired the final session and provided concluding remarks, and Dr. Stanley N. Roscoe for his entertaining and equally informative dinner presentation.

John C. Hemingway
Workshop Chairman

George P. Callas
Co-Workshop Chairman

WORKSHOP SUMMARY

J.S. Seeman

U.S. Army Avionics R&D Command
St. Louis, MO

It seems clear that we are faced with a formidable task over the next few years. Never before have I heard so many traditionally insoluble problems identified as potential research issues. These are being identified as soluble or at least addressable in the near future. With the solutions expected to impact an Army program intended to be fielded in less than 10 years, there is a danger that we have been overly optimistic and may have "bitten off more than we can chew". In order to accomplish even parts of the job, we are going to have to organize and arrange for the cost effective utilization of the resources that are at our command. We do not have unlimited resources. I would like to present some of the specific problems that I see.

The Army indicated that it intends to execute a development program, the LHX. NASA has indicated that it intends to impact the LHX program in it's Pre-Planned Product Improvement (P^3I) phase. P^3I occurs during the latter phase of the LHX program, after the existence of a developed system. It would seem desirable to expedite the NASA effort in some fashion to allow the results of NASA research to impact LHX earlier. May I suggest possibilities on how that might be accomplished?

The LHX program has a need for information that NASA may be able to provide earlier than the P^3I phase. What we are lacking is not the identification of problems (those have been thoroughly identified during this workshop) and not resources (NASA's resources are well known), but tools to expedite the process. Those tools were alluded to in several presentations this morning as well as in the opening remarks by Dr. Statler when he mentioned mathematical system modeling. What would be a highly desirable tool in this field is a method to design and evaluate a cockpit, conceptionally, in advance of the existence of hardware. Needed to implement this would be an acceptable mathematical model of aircrew performance and a system model. These could be "played" against each other to develop data on system performance characteristics.

All of the approaches that have been recommended today, with few exceptions, seem to be attempts to reduce cockpit workload for the aircrew. These approaches base themselves primarily on innovative hardware solutions supported by extensive software capability. Reliance upon such software will be necessitated by future "automated" cockpit operations. Software we know is very expensive and time consuming to produce. An over-riding area that might be addressed by NASA would be to develop methods for the generation and test of software, more efficiently than we do today. Gains in this area can be expected to result in significant cost reductions in future fielded systems.

We have also, during our discussions, seen evidence that each of us brings to bear on his/her problem, his own assessment of the state-of-the-art of technology. I for one feel that I don't know enough of what is happening in the various laboratories throughout this country or the free world to be able to give an accurate assessment of where technology is and what the risks are of incorporating that technology into a program of the nature of the LHX. And, others probably share this difficulty. Might I suggest that NASA consider becoming a repository; a collector and disseminator of information on technology state-of-the-art in various areas of its interests and of relevance to the LHX program. The state-of-the-art repository would be available to industry and government alike and might be very valuable in reducing the risks and the possible premature expenditure of funds in the pursuit of LHX goals.

Throughout the presentations this morning we have seen recommendations for reduced workloads. I come from the tradition, like others, that the technical community doesn't yet know what workload is. We have no definition that's acceptable to practioners in the field. We do not at the moment know how to measure workload. Yet we may be talking about reaching the knee of the curve in achieving efficiency of manned operations in cockpit operations in the LHX. We may also be reaching a point perhaps of achieving diminishing returns in workload reduction with extensive increases in automation. We very much need a workload measurement technique suitable for cockpit design and I think some concerted properly oriented effort might result in some worthwhile gains in this area. A generic workload model may not result from that concerted effort but we might have a better way of measuring what it is those cockpits are providing us in terms of efficiency or ease of operation. I would like to see that workload measurement technique somehow combined with the system mathematical models that I touched upon earlier so that we can, in anticipation of a real cockpit or instrument grouping, identify what the workload penalties or advantages are going to be on our crewmembers activities before we proceed with development. We talk a good deal about workload. But, I think we have done insufficient work in solving the problem.

NASA has a formidable task ahead of it. It has to identify, from the areas of research that we've identified, how it's going to bring it's resources to bear, i.e., how it's going to manage those resources on a priority and cost basis, to solve these problems. Unfortunately, very few of the areas that were mentioned today refer to specific research problems. When researchers are faced with a generic problem area, it's often very tempting for them to identify and concentrate on a problem within that area with which they are familiar. That problem may not be the most relevant research question addressable in that area, nor may it be addressing the questions that require immediate answering. May I suggest that a process be initiated to identify research problems within these generic research areas. I suggest the establishment of a research steering committee composed of personnel within NASA or combined with the Army to help identify specific research issues, and the priorities and schedules to be assigned.

This concludes my observations. I would like to take this opportunity to thank NASA for giving us all this opportunity to interact on research issues and to thank you for the personal honor of having been invited. I would also like to express, with a round of applause, our appreciation to John Hemingway for a job well done in organizing and arranging for this entire meeting.

SESSION 1

INTRODUCTORY PRESENTATIONS BY NASA AND AMRL PARTICIPANTS

OPENING REMARKS

Dr. Irving Statler

U. S. Army Aeromechanics Laboratory
Moffett Field, California

There is no better example of testing the adequacy of man-machine interface than the Army's mission in helicopter flying nap-of-the earth with sophisticated weapon and mission systems in combat and adverse weather. We are about to make a decision about a one-man versus two-man cockpit for the LHX, but we do not have enough information to make an intelligent decision. Consequently, the decision will be based on other things, like political reasons, financial reasons, and economics, while it should be based on an objective evaluation of whether one man can actually do the job. The fact is that we do not have enough information to know whether one or two men or forty-two men can do the job. We use "cut-and-try" methods. We build it and we try it in the course of designing both cockpits and the training systems. We are spending a fortune on training systems because we don't know how to design the system with assurance that it will do an adequate job. We build it for test and evaluation, but we don't even know how to evaluate it. We have no objective evaluation techniques. We desperately need your help in telling us where to go. We need predictive methodology for the cockpit. The critical element is the human pilot. We can play around with figures-of-merit for rotors and aircraft performance, we can improve specific fuel consumption and perhaps structural efficiency; but none of these are show stoppers. None of these will prevent the mission from being accomplished. But if we don't design the cockpit properly, we will prevent the mission from being accomplished, and we won't know why. We aren't going to allow the aircrews in a peace-time environment to get themselves into nasty situations and in the war-time environment we won't know where to put the blame.

Look what we're doing, not only in helicopters but in fixed-wing aircraft as well. That's an F-18 cockpit (Fig. 1). It's probably one of the best examples of what the avionics people choose to call "the integrated cockpit". With three CRT's and a HUD, it has 675 acronyms that can appear on any of three CRT'S. There are one hundred and seventy-seven symbols that can appear in four different sizes. There are seventy-three threat, warning, caution, and advisory messages, fifty-nine indicator lights, six auditory warning tones—no messages, just different warning tones, twenty-two different HUD configurations, forty display formats on the CRT's, nine switches on the throttle (most of which are multifunction), and seven on the stick grip. Tell me, can a guy really handle these in air-to-air combat under six G's?

We have even worse problems in our helicopters because we try to do everything with a single helicopter. See here's our own new Black Hawk (Fig. 2). It's loaded--almost like a 747 cockpit. Now we're trying to give the helicopter pilot the ability to fly at night a few feet off the ground, and so we have to give him a night vision system. This is an example of one (Fig. 3). Forward-looking infra-red imagery, and superimposed on this image are symbologies--symbologies that give flight control information and symbologies that give weapon control information. The flight control symbologies may appear in three different modes. Here are two of them (Fig. 4). There is en-route flight, transition to hover and there may also be a hover and bob-up maneuver mode. As many as 19 different symbols are waving about over this FLIR image. For the pilot of our new Apache, all of this information, the FLIR imagery, the weapon control symbology and the flight control symbology, are presented on a two and one-half centimeter CRT over the pilot's right eye (Fig. 5). The pilot is expected to take care of the peripheral scene and the instrument panel with his other eye. Can he do this while maneuvering a few feet off the ground, in and around trees, under obstacles, avoiding threats, avoiding radars, managing his mission systems and communications? Remember, this is a team operation and he has lots of communication with the Scout, the other attack aircraft, and with the ground.

We are designing our systems with displays and controls without any recognition of the limitations of human perceptual and cognitive capabilities. We're allowing the avionics people to design displays--fancy, beautiful, colorful displays. We're allowing the controls people to design independently, powerful new SCAS systems with their side-stick controllers. Then there are the psychophysiologists who are trying to understand the guy in the middle who is supposed to connect these two things. I suggest to you that we better get together because we're in a real desperate situation in the cockpits of all of our military aircraft, and particularly in our helicopters. I'm sure you'll solve the problem this week. I wish you the very best of luck for an excellent meeting. Good luck, John.

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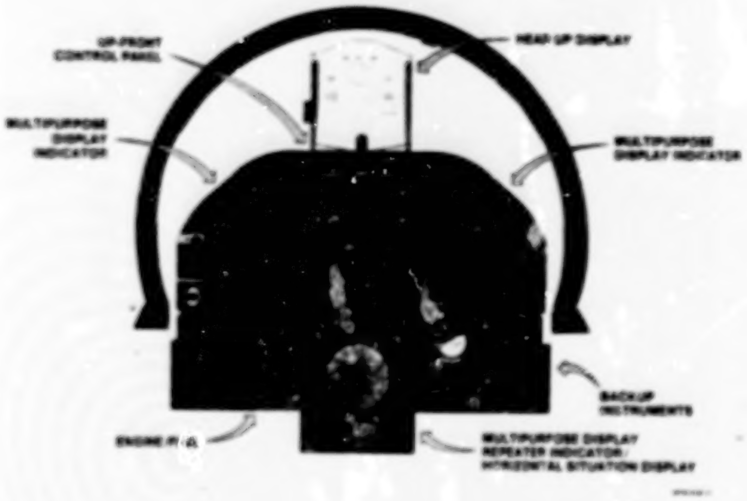
UP-FRONT CONTROL PANEL
HEAD UP DISPLAY
MULTIPURPOSE DISPLAY INDICATOR
MULTIPURPOSE DISPLAY INDICATOR
BACKUP INSTRUMENTS
ENGINE [illegible]
MULTIPURPOSE DISPLAY REPEATER INDICATOR / HORIZONTAL SITUATION DISPLAY

FIG. 1 F-18 COCKPIT

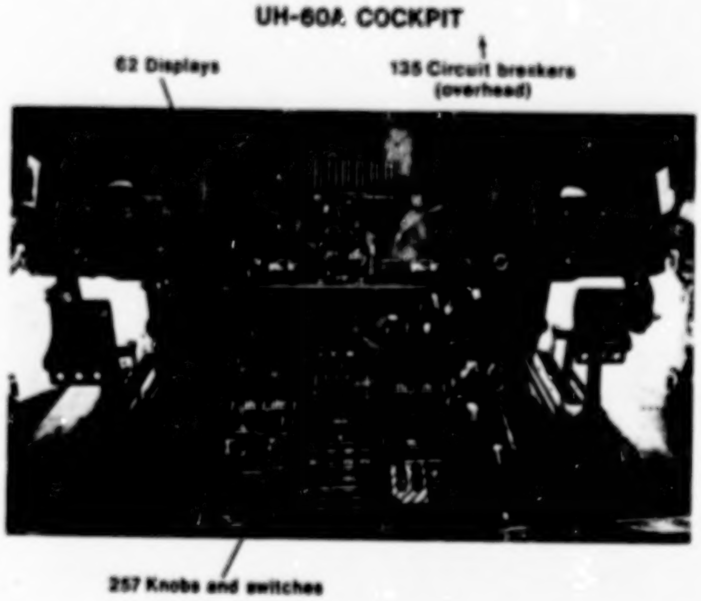
UH-60A COCKPIT
62 Displays
135 Circuit breakers (overhead)
257 Knobs and switches

FIG. 2 UH-60A COCKPIT

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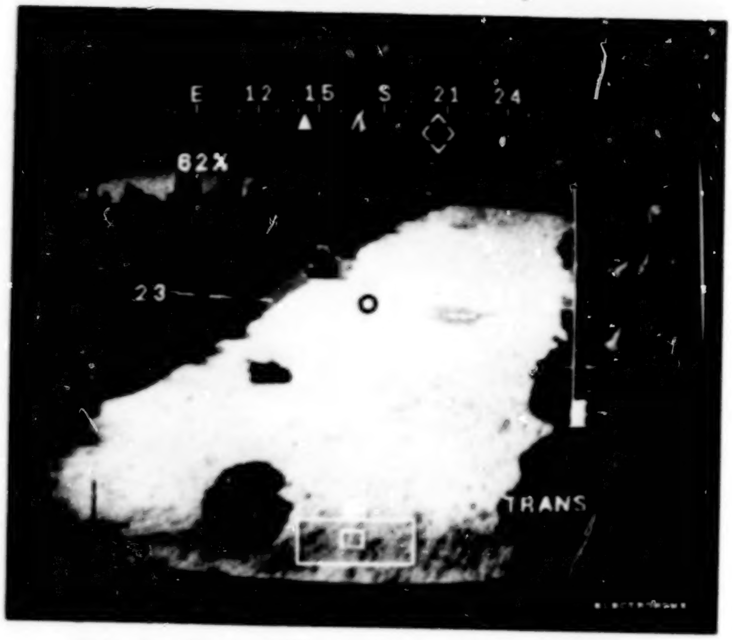
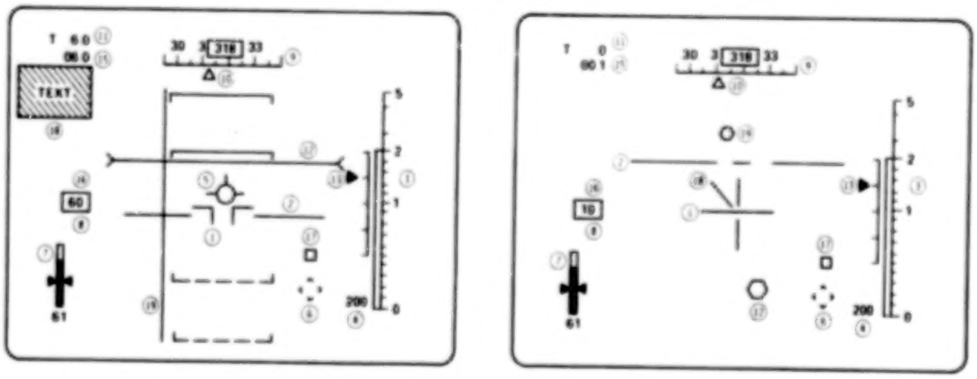


FIG. 3 HELICOPTER NIGHT VISION SYSTEM

PNVS SYMBOLOGY



SYMBOL NAME

① Aircraft symbol
② Horizon/pitch bars
③ Radar altitude (analog)
④ Radar altitude (digital)
⑤ Velocity vector
⑥ IR sensor
⑦ Torque
⑧ Groundspeed/airspeed
⑨ Aircraft heading
⑩ Navigation steering
⑪ Distance to go
⑫ Altitude reference bar
⑬ Vertical speed
⑭ Time to go
⑯ Airspeed indication
⑰ Point of interest
⑱ Failure warning indicator
⑲ Corridor bar

a) Flight

SYMBOL NAME

① Aircraft symbol
② Horizon bars
③ Radar altitude (analog)
④ Radar altitude (digital)
⑥ IR sensor
⑦ Torque
⑧ Groundspeed/airspeed
⑨ Aircraft heading
⑩ Navigation steering
⑪ Distance to go
⑫ Position box
⑬ Vertical speed
⑭ Time to to
⑯ Airspeed indication
⑰ Point of interest
⑲ Hover velocity
⑳ Hover acceleration

b) Hover/transition

FIG. 4 PNVS SYMBOLOGY

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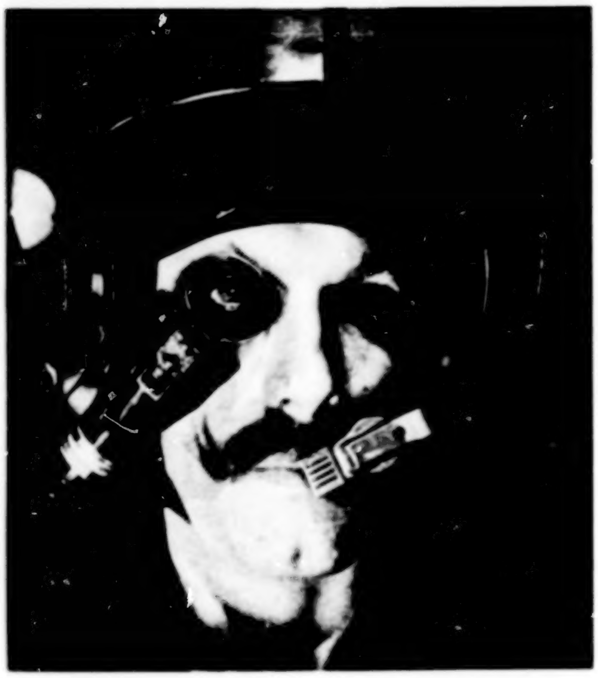

FIG. 5 CRT

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SUPERAUGMENTED ROTORCRAFT PROGRAM

Mr. R. D. Showman

NASA-Ames Research Center
Moffett Field, California

I want to describe a program that we are proposing to the NASA Management. The program is called the Superaugmented Rotorcraft. This program was proposed after the workshop was initiated. Consequently, this presentation does not appear on the agenda. However, it was thought that it would be very beneficial to describe what our views are in terms of a future program. The Superaugmented Rotorcraft Program is being proposed as a FY-86 New Initiative. The objective is to determine the technology that would be required to have a rotorcraft successfully fly a very complex mission in a very severe environment.

We reviewed a number of missions, both civil and military (Fig. 1). For example, in the civil area, medical services and law enforcement, and in the military, LHX Scout and LHX Utility. The missing technology in being able to successfully complete these missions is in the areas of controls, guidance, cockpit, and propulsion but not in those individually. It is in the integration of these technologies. In order to focus our program and also to provide a far-term orientation to the research, we chose a very complex mission and a very severe environment which is oriented very much towards the LHX. It does however, have application to civil missions.

The environment we are considering is Nap-of-the-Earth, low level flying, at night, in all weather, and into and out of remote sights (Fig. 2). The tasks the crew must consider while conducting this mission is guiding the vehicle, surveillance, communicating both with the other helicopters and also with personnel on the ground, navigating, and controlling the vehicle. The crew must also be concerned about the weapons management and aircraft systems management. In addition, we are considering this in the context of the single pilot. So what is the problem?

Currently, the two-man crew is unable to perform the task (Fig. 3). The crew tends to interact through the cockpit with the systems in a fairly straightforward, unsophisticated manner. When you look at the complex missions and severe environment being considered, it is going to require some level of automation, some level of intelligence, and much more capable systems to perform the missions successfully. We are proposing to conduct research only in the control and guidance systems. We are not conducting research in the aircraft communication systems or the mission system. In the control and guidance systems, we will investigate concepts that will successfully perform

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the kind of mission just described; develop systems criteria to allow designers to design systems; and determine the level of intelligence and the automation that will be required because the crew will depend much more heavily on these systems. In addition to being more dependent on the systems, the mission requires a very high workload. Consequently, the pilot's interaction with the systems must be very effective and very efficient. Thus, we want to investigate the cockpit/dialogue system. We need to determine the information requirements as a function of different phases of the mission, and to determine how to present the information to him (i.e., voice, CRT displays, etc.). Also, how does the pilot enter information into this system (i.e., voice, keyboard, etc.)? The other program element called Integrating Intelligence, is aimed at investigating the allocation of tasks between the pilot and the systems. We will study the requirements for automation and for intelligence in the system, the pilot-system interface, and the functional integration of the systems.

The program goal is to validate concepts, design criteria, and methodology in four areas: control systems, guidance systems, cockpit-dialogue systems, and the integrated intelligence. The approach is to investigate these areas in an individual manner through analysis and simulation and in an integrated manner through simulation and flight (Fig. 4). Finally, the integrated concepts will be validated in flight.

The NASA Superaugmented Rotorcraft Program and the Army "ARTI" (Advanced Rotorcraft Technology Integration) Program are complementary programs which will support the LHX development. The ARTI Program, Phase I and Phase II, will provide technology for the development of the LHX systems specification and the full scale development. The Superaugmented Rotorcraft Program will initially be building on the Army's ARTI Program. The program will provide the technology both for the full-scale development and for the P^3I (Pre-Planned Product Improvement) Program (Fig. 5).

We will now describe the four program areas. I'll describe the control system very briefly, Dr. Huff will describe the Cockpit-Dialogue system, and Dr. Denery will describe the guidance system and the integrating intelligence. Let me describe the control system first. The control program consists of two elements (Fig. 6). One is digital active flight propulsion controls and the other is configuration design studies. In the digital active flight-propulsion control study, the objectives are precise flight path control, extended operational envelope, and reduced attention for control and monitoring. The flight-propulsion control integration item is the integration of the flight control system to provide precise flight path control and to reduce the crew time for controlling and monitoring the vehicle. The second item is envelope enhancement which will provide the crew with the full envelope required to fly Nap-of-the-Earth missions. If done properly, it will result in an expanded operational envelope and reduced attention for the control monitoring task. The second element is configuration design studies which will define the influence of the control technology on the configuration and also the effect of the configuration on the control technology.

Dr. Huff will now describe the cockpit-dialogue system program.

TECHNOLOGIES FOR IMPROVED MISSION PERFORMANCE

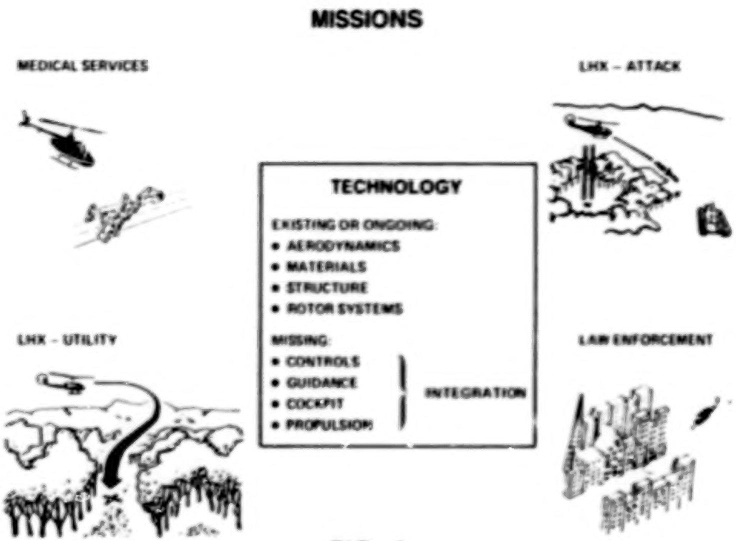

MISSIONS
MEDICAL SERVICES
LHX – ATTACK
TECHNOLOGY
EXISTING OR ONGOING:
• AERODYNAMICS
• MATERIALS
• STRUCTURE
• ROTOR SYSTEMS
MISSING:
• CONTROLS
• GUIDANCE
• COCKPIT
• PROPULSION
INTEGRATION
LHX – UTILITY
LAW ENFORCEMENT

FIG. 1

SUPERAUGMENTED ROTORCRAFT TECHNOLOGY

ENVIRONMENT/TASK DRIVERS

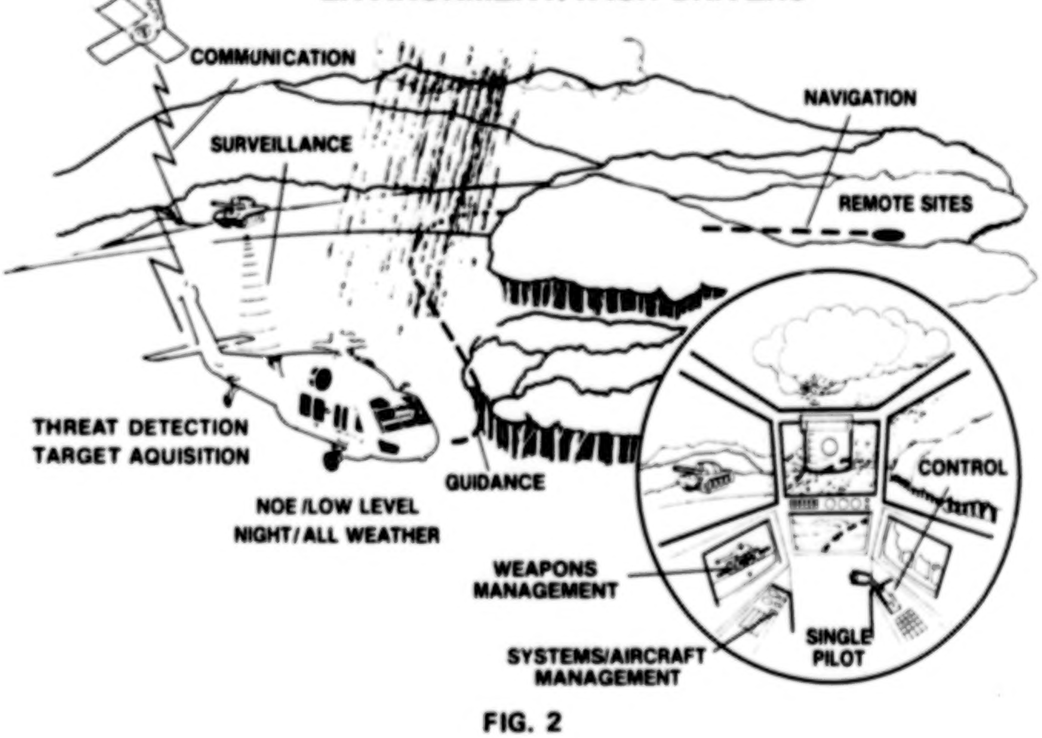
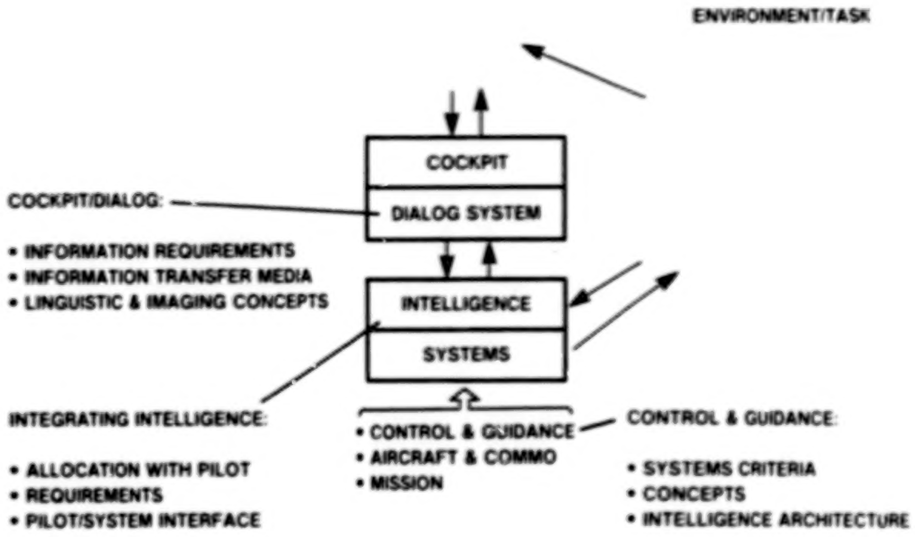

COMMUNICATION
NAVIGATION
SURVEILLANCE
REMOTE SITES
THREAT DETECTION
TARGET AQUISITION
GUIDANCE
NOE /LOW LEVEL
NIGHT/ ALL WEATHER
CONTROL
WEAPONS
MANAGEMENT
SYSTEMS/AIRCRAFT
MANAGEMENT
SINGLE
PILOT

FIG. 2

THE TECHNOLOGY "ROADBLOCK"

- PILOT/COPILOT CURRENTLY UNABLE TO PERFORM TASKS
- AUTOMATION/INTELLIGENT SYSTEMS *REQUIRED* TO PERFORM TASKS



ENVIRONMENT/TASK

COCKPIT

DIALOG SYSTEM

INTELLIGENCE

SYSTEMS

COCKPIT/DIALOG:

- INFORMATION REQUIREMENTS
- INFORMATION TRANSFER MEDIA
- LINGUISTIC & IMAGING CONCEPTS

INTEGRATING INTELLIGENCE:

- ALLOCATION WITH PILOT
- REQUIREMENTS
- PILOT/SYSTEM INTERFACE

- CONTROL & GUIDANCE
- AIRCRAFT & COMMO
- MISSION

CONTROL & GUIDANCE:

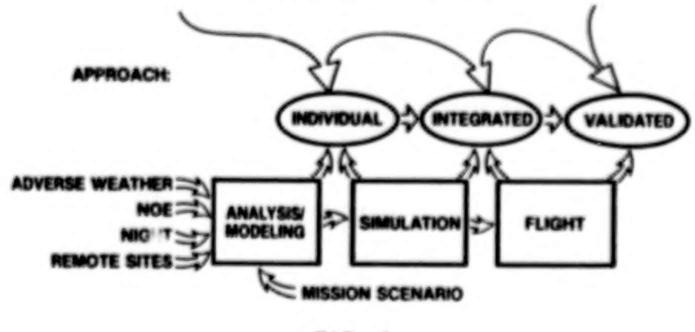
- SYSTEMS CRITERIA
- CONCEPTS
- INTELLIGENCE ARCHITECTURE

FIG. 3

SUPERAUGMENTED ROTORCRAFT TECHNOLOGY
PROGRAM

GOAL: VALIDATED CONCEPTS & DESIGN CRITERIA/METHODOLOGY

- CONTROL SYSTEM
- GUIDANCE SYSTEM
- COCKPIT/DIALOG SYSTEM
- INTEGRATING INTELLIGENCE



APPROACH:

INDIVIDUAL

INTEGRATED

VALIDATED

ADVERSE WEATHER

NOE

NIGHT

REMOTE SITES

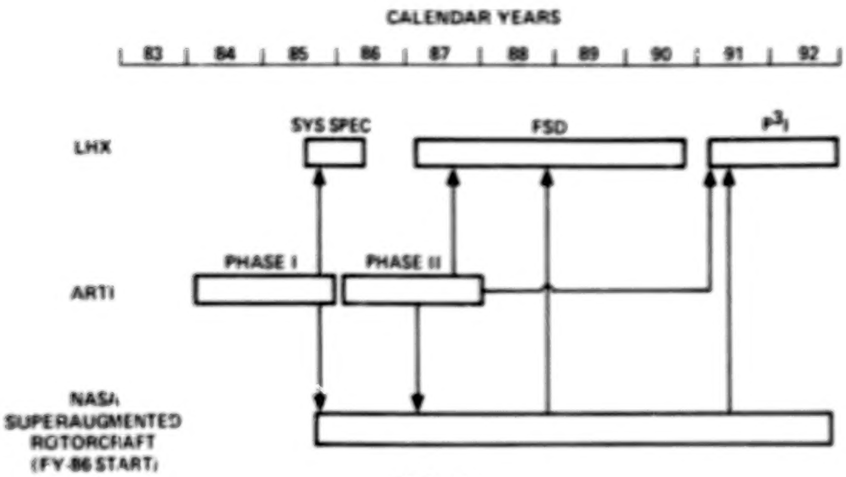
ANALYSIS/ MODELING

SIMULATION

FLIGHT

MISSION SCENARIO

FIG. 4



SUPERAUGMENTED ROTORCRAFT PROGRAM RELATIONSHIP TO LHX AND ARTI

CALENDAR YEARS
83
84
85
86
87
88
89
90
91
92
SYS SPEC
FSD
P^3I
LHX
PHASE I
PHASE II
ARTI
NASA SUPERAUGMENTED ROTORCRAFT (FY-86 START)

FIG. 5

CONTROLS

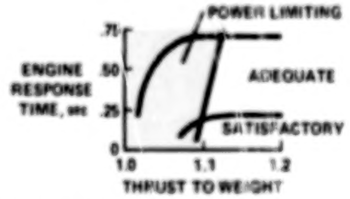
OBJECTIVES

- PRECISE FLIGHTPATH CONTROL
- EXPANDED OPERATIONAL ENVELOPE
- REDUCED ATTENTION FOR CONTROL AND MONITORING
- DEFINE INFLUENCE OF CONTROL TECHNOLOGY ON CONFIGURATION
- DEFINE DIGITAL CONTROL DESIGN METHODOLOGY

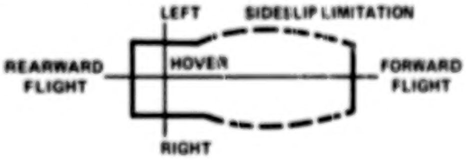
APPROACH

DIGITAL ACTIVE FLIGHT-PROPULSION CONTROLS

- FLIGHT-PROPULSION CONTROL INTEGRATION

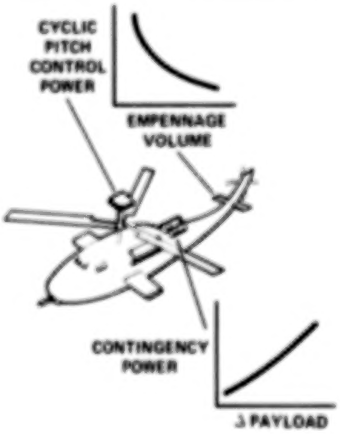


- ENVELOPE ENHANCEMENT



LEFT
SIDESLIP LIMITATION
REARWARD FLIGHT
HOVER
FORWARD FLIGHT
RIGHT

CONFIGURATION DESIGN STUDIES



CYCLIC PITCH CONTROL POWER
EMPENNAGE VOLUME
CONTINGENCY POWER
Δ PAYLOAD

FIG. 6

N85 14808

D2

HELICOPTER HUMAN FACTORS PROGRAMS AND PLANS

Dr. E. M. Huff

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During this part of the presentation, (Fig. 1), I would like to review the Cockpit Dialog portion of the Superaugmented Rotorcraft (SAR) program, and to point out certain conceptions we have as to the development problems and what needs to be done by way of research.

Since we are talking about a single-pilot rotorcraft, flying in a highly dangerous environment, the most obvious problem is the potential for overburdening the pilot. Somehow we have to reduce the information processing requirements on him. In order to do this we basically have two things working for us. The first is the pilot's untapped capabilities. The second is microcomputer technology. In short, we need to make much better use of the pilot's natural abilities -- and to do this, the use of advanced technology will be required.

One of the primary themes I will present here, and which you may wish to discuss at greater length in the Workshop, is that much greater advantage could, and probably should, be taken of the pilot's linguistic information processing capabilities. Although the use of language is, in fact, one of the essential and defining characteristics of the human species, to date this unique communications ability has not been integrated systematically into man-machine systems. Other human abilities, such as those for processing visual symbolic information, are used much more routinely -- but even here advances must be made to properly blend the symbolic and linguistic forms. With the use of speech recognition and synthesis devices, as well as advanced visual displays then, we may have a means for resolving the single-pilot issue.

I would now like to discuss the problem of compensating for the lack of a co-pilot (Fig. 2). When I first used this viewgraph, I think the audience thought I was saying that the pilot had to be "cracked" to fly in a situation like this. However true that may be, it was not the intent. The idea that I'd like to convey, rather, is that we are really dealing with a "collage" -- hence, the picture of the pilot as a composite. When we talk about the future single pilot's duties, we should think about a combination of non-automatable functions taken from what used to be the pilot's and co-pilot's roles. Added to this are new performance requirements which are induced by the automation itself. It's simply not reasonable to say that we are going to "automate the co-pilot", meaning that we will replace the co-pilot en toto with an automatic system. I don't think technology has come along that far. It is conceivable,

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however, that if we consider very carefully what is automatable in the pilot's and co-pilot's duties for Nap-of-the-Earth and other low level obstacle avoidance flight, that perhaps, if we did our job right, we might have non-automatable functions left which could be done collectively by a single person. If not, I'm afraid we'd better scratch that idea and work on something else. That's the bottom line.

Programmatically, we have three things to concern ourselves with in general. First, at the top level, is the capability of the pilot himself. He has sensory apparatus, such as ears and eyes, as well as output mechanisms. At Ames we have ongoing activities which look at this sort of information processing ability in a fairly fundamental way. Second, we have the media in the cockpit itself to be concerned with. Dr. Statler has already talked about the limitations of input to the pilot by way of conventional information displays. Our present work, therefore, is concentrated on the auditory mechanism largely because that, to a very large extent, is not used as much as it might be. On the pilot input side to the helicopter, we seem to use every appendage that the pilot has. We use his hands, his feet, his fingers and pretty soon we will probably use his toes. There are conventional keyboards, and such, but again we can take advantage of linguistic abilities with speech recognition technology. And somehow we have to integrate that with the conventional means of information transfer. Our present program has a strong thrust in that direction. Finally, we now have the microcomputer available, which the human has to be connected with.

Here I have briefly outlined what I believe some of the essential elements of an advanced system will have to be. Probably some kind of dialog controller: software which provides a two-way interface between the man and rest of the system. Having gone through the controller, there will be a specific need for some form of language syntax (or grammar) structure to be worked out. The translation of that output, in turn, will occur in some form of message understanding software, -- so that the rest of the system can understand, in it's own terms, what the pilot is trying to communicate. And then, comming back the other way, another function for message understanding will be to translate what the system has to convey to the human in terms that he understands. Finally, the messages will have to be prioritized in some fashion -- as we have many subsystems in the total system. We can assume that at any given time, a number of them will be competing for the pilot's attention. Closing the loop, the dialog controller needs to be involved again in resolving the immediate input and the output cockpit media requirements.

In brief summary, then, we need to advance our understanding of what is realistically automatable. We need to develop an understanding of design concepts for pilot interaction with highly computerized systems and particularly the dialog aspects: that is, the transfer of information back and forth between the pilot and the system. This is the firmware and the software so to speak. We need to develop principles for blending the various IO media, particularly the linguistic media and conventional media. And then, as if that's not enough, we need to address the last three areas. Namely, we need to develop those applied AI aspects dealing with input and output grammar, message understanding, and message prioritization. Finally, there is a very difficult area, and one that blends into what Dallas Denery will talk about shortly, the whole domain of computer prompting, pilot query and decision aiding.

(Figure 3) Many of the things I've mentioned have been talked about for years, but have not yet been realized to any great extent, even for vehicles on the drawing board. Fortunately, however, there has also been a considerable amount of work. I've listed here just some of the projects that we are familiar with, and I hope I don't hurt anyone's feelings if I have left out your favorite. The point is that there is a background to the linguistic area.

Fortunately we have Bob Wherry here today to describe the Navy's VRAS program. Or, he will talk about related matters at least during the course of the program.

There is a program much related in many ways: the AFTI F-16 use of linguistics speech input and output media.

There are Navy applications which have been quite successful in flight training systems and command control applications.

Of course, there is a whole array of industrial production line applications and such.

Notice, that to a large extent, these are all speech applications in a much more benign environment than what we have to contend with for low-level helicopter flight.....with the exception of the current F-16 program.

(Figure 4) Over the last few years we have done a considerable amount of work in this and related areas. I really can't go into all of it completely during the course of this meeting. This is the capability that we developed over the last few years. It's a tandom helicopter cab, but here you can only see the front cockpit. It's right upstairs above us. The cockpit is fairly realistic at least in a general sense with regard to helicopters. It has the proper controls and panel displays.

But, you will also notice the strange display on the top that Capt. Voorhees sitting there is looking at (Fig. 5). This is a visual task that we developed, called "SHAMSIM" (Standard Helicopter Abstract Mission Simulation). We created it in order to get some cost effective way of looking at dynamic flight task performance in a Nap-of-the-Earth environment. Clearly, this is not a high fidelity visual simulation. We do believe it's a bit clever, though, and that it will generalize behaviorally to the real world, and that perhaps some of the ideas could be put into more realistic simulators. I won't go into this in detail. What you are looking at is a plan-like view of a forest. The "X"s represent trees. It's not quite a plan view though. If you think of the trees from the side prospective as being two intersecting isosceles triangles that meet at a common apex, then what you are looking at is a plane cut through those trees at the altitude of the vehicle. The helicopter, incidently, is the circle in the center. I won't go into what the "C"s and the "8"s are at this point, but they represent generic radar threats from one of the applications for which we used this simulation.

Using this simulation capability, we have done two types of studies looking at helicopter speech applications (Fig. 6). The first we called "SCADS" (Speech Command Auditory Display Systems), where we were examining both input and output of speech information. Very briefly, the pilot had an opportunity to request flight data vocally, e.g., airspeed, altitude and torque, and it was played back to him via speech synthesizer. At least that was one of the conditions that we ran. We compared that with a conventional panel display and a HUD type of display. The results of that study clearly indicated that for Nap-of-the-Earth flight, where there's considerable need to look outside (in this case at the simulated scene), not having to look at the panel was a great advantage, and not having to look at the HUD was almost as great as an advantage. Insofar as the complex tradeoffs required in this mission are concerned, therefore, it seems that better overall performance is obtained with speech technology than with other media for flight parameter types of information transfer.

(Figure 7) We are just finishing this a project having to do with the design of an advanced radar threat warning system. Again, not much detail. We have been involved with not only the visual aspects of it, which are symbolic, but also a speech message delivery system which will annunciate the identity of the threat, the location of the threat, and how dangerous it is. After having gone through this research, it's very clear to us that we were lucky to get involved in this unique project, because we learned so much. Here is an area where we are dealing with advising the pilot of survival threats in his immediate surround, and where speech technology is not just nice to have. Speech (production) technology is probably necessary to have. This is reflected in the fact that after some experience with this system, which has both new visual and auditory capabilities, the seven electronic warfare (EW) pilots that we were dealing with were equally divided as to whether they would rather loose the visual or the auditory capability -- given a failure in the system. The lesson we learned is that the two forms of display serve somewhat different purposes, and that pilots recognize the unique value of the auditory mode. It appears to make life a whole lot simpler for them to have it -- so that's encouraging.

(Figure 8) To summarize this part of the program, then, and to give you some food for thought, we are not necessarily restricted to this set of research elements. If you don't agree with what has been presented, then this is your opportunity to say what and why -- and what should be done. At least as I have discussed it thus far, we look to you, the industry, for helping us with analysis of automatable crew functions. We don't have all of the experience that is required in order to fully understand what is automatable or even what should be automated. Once that's done in some way, we must then synthesize the information requirements for a single pilot. Again, your help will be necessary. Along these lines, there have to be concepts developed for how to blend the various input and out media in the cockpit. Also keep in mind the applied linguistic and artificial intelligence algorithms that have to be an integral part of this system.

Back in our laboratories and simulators we anticipate looking at the various mixing concepts that you help us to define for cockpit media, and also to evaluate the different linguistic and symbolic rules that emerge, I might add. Here I'm using the word "linguistic" in a larger sense than simply speech technology. Also, we expect to evaluate proposed AI technology which clearly includes computer prompting, decision aiding and a whole array of things that we probably haven't clearly thought out yet. Some of these ideas were suggested earlier by Bob Showman. Much of this will be done in the spirit of proof of concept, or exploratory investigations. Comparisons that we can't make in a simulator will need to be made in flight.

That, in short, is what the Cockpit-Dialog part of the program is currently defined to be, and as I've mentioned before we would really appreciate your help in scoping it out further. Now I'll give the podium to Dallas Denery, who will present some related aspects of the program concerning "Integrating Intelligence".

HELICOPTER COCKPIT/DIALOG SYSTEM RESEARCH

NEEDS

- REDUCE INFORMATION PROCESSING REQUIREMENTS ON PILOT
  (UNBURDEN PILOT)
- DETERMINE OPTIMAL USE OF SYMBOLIC AND LINGUISTIC TECHNOLOGY
  (MAKE BETTER USE OF PILOT)
- ESTABLISH VALUE OF COMPUTER PROMPTING, PILOT QUERY AND DECISION AIDING TECHNIQUES
  (COMPENSATE FOR LACK OF COPILOT)

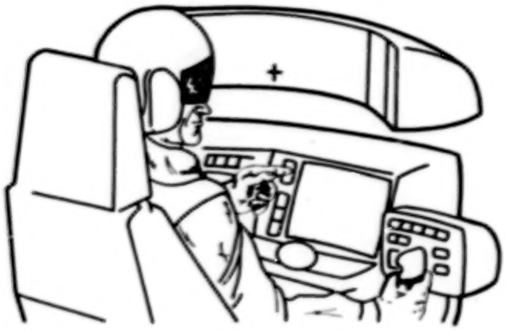

FIG. 1

COCKPIT/DIALOG SYSTEM

OBJECTIVES:
- PRINCIPLES FOR INTERACTIVE PILOT SYSTEM DIALOG
- BLENDING OF SYMBOLIC AND LINGUISTIC TECHNOLOGY
- COCKPIT DISPLAY AND CONTROL REQUIREMENTS
- VALUE OF PILOT QUERY, COMPUTER PROMPTING AND DECISION AIDING SYSTEM INTELLIGENCE

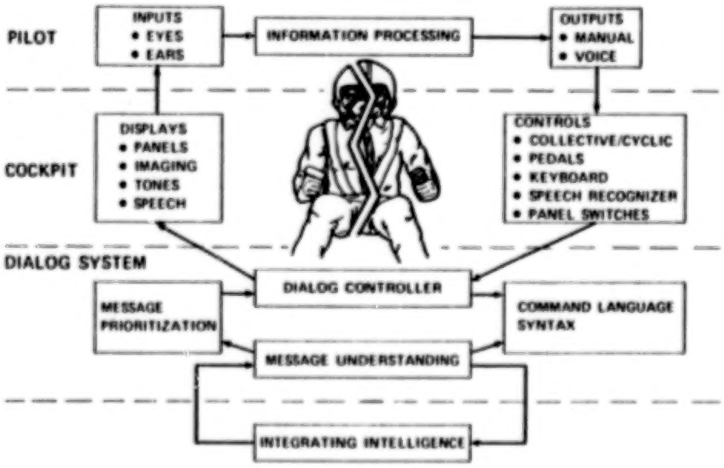
PILOT
INPUTS
• EYES
• EARS
INFORMATION PROCESSING
OUTPUTS
• MANUAL
• VOICE
COCKPIT
DISPLAYS
• PANELS
• IMAGING
• TONES
• SPEECH
CONTROLS
• COLLECTIVE/CYCLIC
• PEDALS
• KEYBOARD
• SPEECH RECOGNIZER
• PANEL SWITCHES
DIALOG SYSTEM
DIALOG CONTROLLER
MESSAGE PRIORITIZATION
COMMAND LANGUAGE SYNTAX
MESSAGE UNDERSTANDING
INTEGRATING INTELLIGENCE

FIG. 2

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HELICOPTER COCKPIT/DIALOG SYSTEM RESEARCH

RELATED LINGUISTIC PROGRAMS

- USN VOICE RECOGNITION AND SYNTHESIS (VRAS) PROGRAM
- USAF AFTI F-16 PROGRAM (GENERAL DYNAMICS)
- USN APPLICATIONS OF SPEECH I/O TO FLIGHT TRAINING SYSTEMS
- USN COMMAND AND CONTROL SYSTEM APPLICATIONS
- INDUSTRIAL PRODUCTION LINE APPLICATIONS OF SPEECH INPUT
- BUSINESS COMPUTER EXPLORATORY DEVELOPMENT

FIG. 3

FIG. 4

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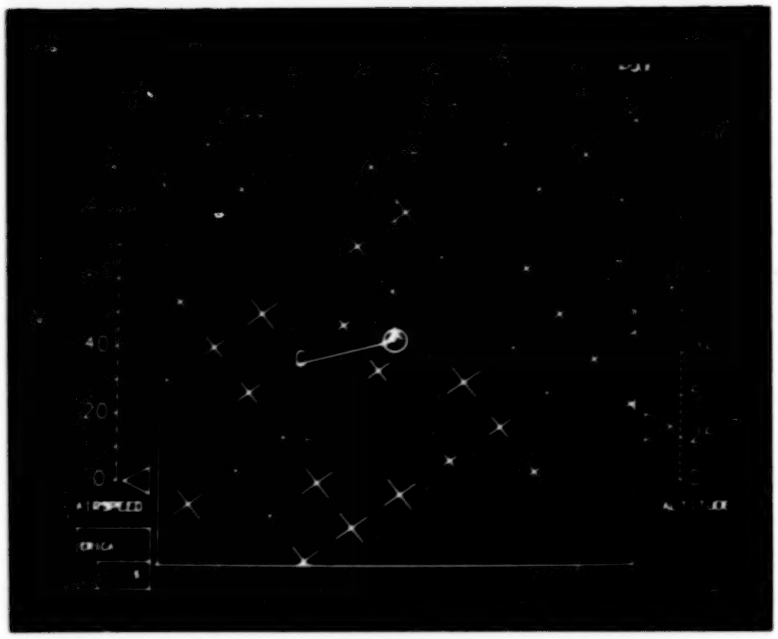
40
20
0
AIRSPEED
ALTITUDE

FIG. 5

HELICOPTER COCKPIT/DIALOG SYSTEM RESEARCH

AMES BACKGROUND

SCADS
(SPEECH COMMAND AUDITORY DISPLAY)

OBJECTIVES:

- EVALUATE SPEECH RECOGNITION FOR FLIGHT DATA REQUEST
- EVALUATE SYNTHETIC SPEECH FEEDBACK IN DYNAMIC NOE TASK
- REDUCE PILOT VISUAL CONFLICT AND WORKLOAD

RESULTS:

- LINGUISTIC TECHNOLOGY BEST FOR STATE INFORMATION
- NOE MANEUVERING BETTER THAN WITH STANDARD INSTRUMENTS OR HUD

DIRECT VOICE INPUT

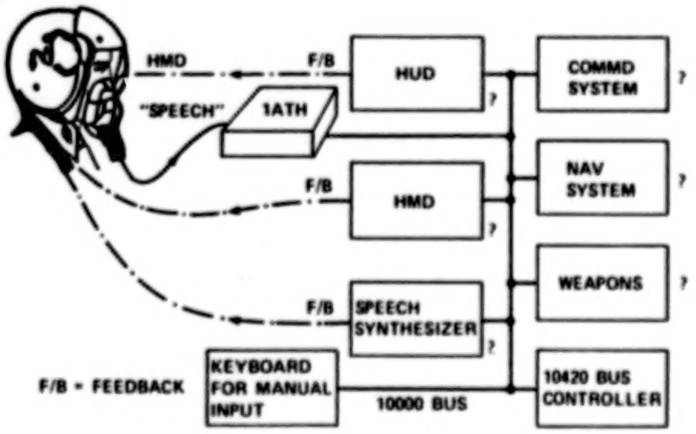
HMD
F/B
HUD
?
COMMD SYSTEM
?
"SPEECH"
1ATH
F/B
HMD
?
NAV SYSTEM
?
WEAPONS
?
F/B
SPEECH SYNTHESIZER
?
F/B = FEEDBACK
KEYBOARD FOR MANUAL INPUT
10000 BUS
10420 BUS CONTROLLER

FIG. 6

HELICOPTER COCKPIT/DIALOG SYSTEM RESEARCH

AMES BACKGROUND

VIEWS
(VOICE INTERACTIVE ELECTRONIC WARNING SYSTEM)

OBJECTIVE

- EVALUATE VISUAL THREAT SYMBOLOGY
- DEVELOP RADAR THREAT SPEECH MESSAGES
- DEVELOP MESSAGE DELIVERY ALGORITHM

RESULTS

- SPEECH REQUIRED FOR EFFECTIVE SYSTEM USE
- PILOTS PLACE EQUAL VALUE ON AUDITORY DISPLAY

CURRENT APR-39A

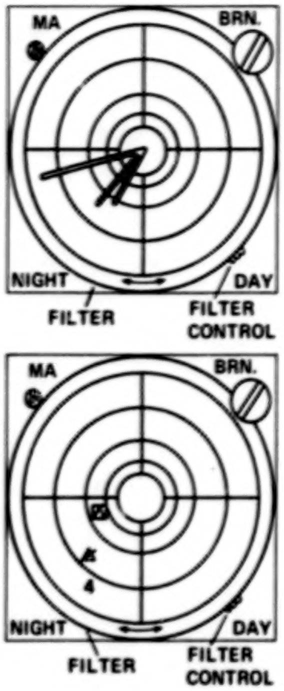
MA
BRN.
NIGHT
DAY
FILTER
FILTER CONTROL
MA
BRN.
4
NIGHT
DAY
FILTER
FILTER CONTROL

FIG. 7

HELICOPTER COCKPIT/DIALOG SYSTEM RESEARCH

APPROACH

ADVANCE UNDERSTANDING OF:

- REALISTICALLY AUTOMATABLE PILOT/COPILOT FUNCTIONS
- DESIGN CONCEPTS FOR PILOT-COMPUTERIZED SYSTEM DIALOG
- PRINCIPLES FOR BLENDING ADVANCED LINGUISTIC MEDIA WITH CONVENTIONAL KEYBOARD/VISUALS
- COMMAND LANGUAGE AND MESSAGE UNDERSTANDING SOFTWARE
- OUTPUT MESSAGE CONSTRUCTION AND PRIORITY SOFTWARE
- COMPUTER PROMPTING, PILOT QUERY AND DECISION AIDING TECHNIQUES

HELICOPTER COCKPIT/DIALOG SYSTEM RESEARCH

PROGRAM ELEMENTS

- INDUSTRY/UNIVERSITY STUDIES
  - ANALYSIS OF AUTOMATABLE CREW FUNCTIONS
  - SYNTHESIS OF SINGLE PILOT INFORMATION REQUIREMENTS
  - ADVANCED I/O MEDIA COCKPIT DESIGN CONCEPTS
  - APPLIED LINGUISTIC AI ALGORITHMS
- LABORATORY/SIMULATOR STUDIES
  - COMPARISON OF I/O MEDIA MIXING CONCEPTS
  - EVALUATION OF INPUT-OUTPUT LINGUISTIC RULES
  - EVALUATION OF AI FOR PILOT QUERY, PROMPTING AND DECISION AIDING
- FLIGHT STUDIES
  - VALIDATIONS IN LOW-LEVEL FLIGHT CONTEXT
  - COMPARISONS OF ONE- vs. TWO-MAN PERFORMANCE

FIG. 8

D3

N85 14809

GUIDANCE AND NAVIGATION PROGRAMS AND PLANS

Dr. D. G. Denery

NASA-Ames Research Center
Moffett Field, California

I would like to review the ongoing rotorcraft activities within the Aircraft Guidance and Navigation Branch, and our plans regarding the Superaugmented Rotorcraft Program (Fig. 1). One goal of the Aircraft Guidance and Navigation Branch is to develop and validate system technology concepts for all weather helicopter operations in both remote and high density areas. We are using our SH-3G to support the remote-area investigations. The primary emphasis has been on the development of advanced navigation concepts to allow rotorcraft to land in remote areas where there may not be a ground based navigational aid. The program has focused on the use of airborne weather radar, the use of high resolution radar, and the use of satellite-based navigation concepts. The high density work has been conducted using our UH-1H helicopter equipped with the VSTOLAND system; this is a research system that allows alternative guidance and navigation algorithms to be tested in flight. The primary emphasis here being to look at landing requirements when flying against microwave landing systems. These tests are being conducted in close cooperation with the FAA, with primary emphasis being on civilian versus military applications.

The airborne weather radar activity started in a cooperative activity with the FAA about four or five years ago and led to the development of criteria for making approaches over water in low visibility conditions (Fig. 2). That activity led to the ehancement of the airborne weather radar with superimposed symbology to improve system effectiveness. The work has also addressed the over land problem, and has evolved into the development of a "beacon landing system" which effectively allows the pilot to use his onboard weather radar receiver to obtain an ILS type of signal for approach and landing.

Our high resolution radar activity has centered on imaging guidance concepts which would enable a zero-zero visibility landing capability (Fig.3). The intent is to develop a preliminary design for such a system based on imaging guidance concepts. The activity includes a contract with Bell Helicopter to look at control and display requirements that can be used with an image sensor in order to provide a zero visibility landing capability. That activity will lead to a simulation at Bell in the later part of August followed by a simulation on the Vertical Motion Simulator in about one year. The activity is supported by: 1) the development of a high resolution radar simulation capability which can be used in the Vertical

Motion Simulator; and 2) a study with the University of California at Davis oriented towards image enhancement techniques that can be used to improve the resolution of high resolution radar image pictures.

Our satellite guidance and navigation concept activities are based on the DOD sponsored GPS system (Fig. 4). We are looking at the "C" code, which is the civilian portion of that system, in a differential mode to provide Category I guidance and landing information. Two study contracts have been completed which examined alternative differential GPS mechanizations to determine the errors associated with the different mechanizations. We have also done some limited flight test in our SH-3G to gain some basic data on the "C" code error characteristics.

I would now like to talk about the guidance and integrating intelligence portions of the Superaugmented Rotorcraft New Initiative. The primary driver behind the guidance portion of the new initiative is defined by the mission itself. The Nap-of-the-Earth, single pilot, all weather/night mission requires an optical detection and avoidance capability, a precise low altitude navigation capability, and a capability to land under poor visibility conditions in a remote area (Fig. 5). In order to accomplish such a mission, a pilot must take full advantage of all sensors onboard his helicopter (Fig. 6). It is necessary to process information in a way that it can be used by the pilot to accomplish his mission. Included would be inertial type sensors, radio sensors, and imaging sensors. Primary research areas will include display and control requirements, and techniques that can be used to process information in a way that the pilot can effectively use it to complete his mission, or alternatively feed it into the control system for those parts of the mission that can be automated. The work will include the generation of guidance laws for the flight director, or trajectory generation in order to minimize exposure to enemy threats while navigating through a hostile environment. It will also include data fusion technology. How do you combine the basic sensor data to provide an accurate estimate of the total vehicle state that can be used to define the pilot displays, or be used in the control system to provide precise flight path control, and how can you blend complementary imaging sensors to provide a single image that the pilot can use in the most effective manner to accomplish his mission?

The last element is referred to as the integrating intelligence portion of the program (Fig. 7). The primary driver here is the recognition that as you design more and more complex systems with their individual control, guidance, navigation, mission management subsystems and pilot interfaces, a whole new area of concern arises which has to do with the integrating logic required to tie these individual elements together into a total system capable of performing the intended mission. The problem becomes even more apparent when you try to define the requirements for a system that will allow a single pilot to perform a task that is currently very difficult for two pilots to perform. A second concern is how to assure that the total system is taken into account in guiding the research activities that must be conducted in the individual areas of control, guidance and navigation, and cockpit dialogue. These two concerns constitute the objectives of this program element. The first objective is to provide the information required for the functional design of a fully integrated flight guidance and control system. The issues involved are determination of optimal allocation of functions between the pilot and system. Which tasks should be automated versus which should be retained by the pilot and how is that allocation affected by a mission senario that involves dynamic switching between a control, navigation, or communications task? What is the integrating logic or intelligence required to integrate the various functional requirements? What techniques can be used to assess the performance of the final design? What's the role of analysis? What's the role of simulation? What's the role of flight test short of operational experience? The second objective is to provide a baseline research system capability which can be used to evaluate alternative integrating intelligent schemes as well as to provide a basic architecture within which individual elements of guidance, control and cockpit dialogue can be evaluated from a total systems viewpoint.

The approach that should be taken in accomplishing this program element is not clear. A program that was recently completed within the Aircraft Guidance and Navigation Branch that addressed such integration issues was the Demonstration Advanced Avionics Systems Program (Fig. 8). The objective of this program was to provide information required for the design of fully integrated avionics suitable for general aviation in the 1980's and beyond. The primary driver was to provide a system that would incorporate conventional capabilities normally associated with general aviation aircraft operations. These included guidance, navigation, flight control, engine and configuration monitoring, emergency and normal checklists, maintenance, and flight status. The purpose was not to improve any one of these functions independently, but rather to look at requirements for integrating different capabilities into a single system, while trying to automate links that are normally provided by the pilot, while still allowing him to access those specific functions directly that are necessary to complete the mission (Figs. 9 and 10). Issues addressed in that program were the pilot system interface, and the architectural design. How do you build a system such that it can offer necessary reliability, maintainability, and modularity but remain affordable? The program led to a contract with King Radio and Honeywell for the design and construction of a system that was installed in a Cessna 402. The pilot interface was accomplished through the use of a distributed, micro-processor-based system architecture, using a common bus to share the processor and display resources.

There are two major differences between what was done in the Demonstration Advanced Avionics System Program and what we are planning in the Rotorcraft Program. First, the DAAS Program was a demonstration program, and consequently evolved towards a single point design. The intent in the Rotorcraft Program is to provide a more basic understanding of systems integration, and how it effects the pilots' ability to successfully conduct the mission. The system that is developed in support of this activity must also offer a research capability to permit alternative integrating intelligence concepts to be investigated. Second, whereas the DAAS program addressed the architectural aspects of the problem, the Superaugmented Rotorcraft Program will not consider architectural issues at all.

The planned approach is illustrated on the next viewgraph (Fig. 11). The first phase is devoted to a series of system studies to define alternative integrating logic schemes, to understand the design principals involved, and to identify evaluation techniques that would be useful in evaluating the effectiveness of alternative schemes. The primary difficulty in trying to accomplish this task is the tremendous resources involved in developing alternative integrated systems in sufficient detail that comparisons can be made. Fortunately, there are several programs ongoing, or recently completed which demonstrate a very high level of integration. These programs may serve as a data base for identifying alternative integrating logic schemes. The two outputs of this phase of the program will be: 1) an identification of the test variables to be examined in the program, and the development of a basic analytical capability for evaluating integrated system concepts, and 2) the definition of the research system which could be used in simulation and in flight test to evaluate alternative integrating intelligence concepts, as well as provide a baseline architecture within which cockpit dialogue concepts, the controls concepts, and the guidance concepts can be tested in the context of a total system. The approach that should be taken to develop this research system is not clear at this time, but it seems reasonable that it could be a reduced version of one of the systems that are being developed under an existing program modified in such a way that it has the flexibility in the software and in the hardware interfaces to permit evaluation of alternative concepts. This basically concludes my presentation; we welcome any thoughts you may have regarding the direction of our program.

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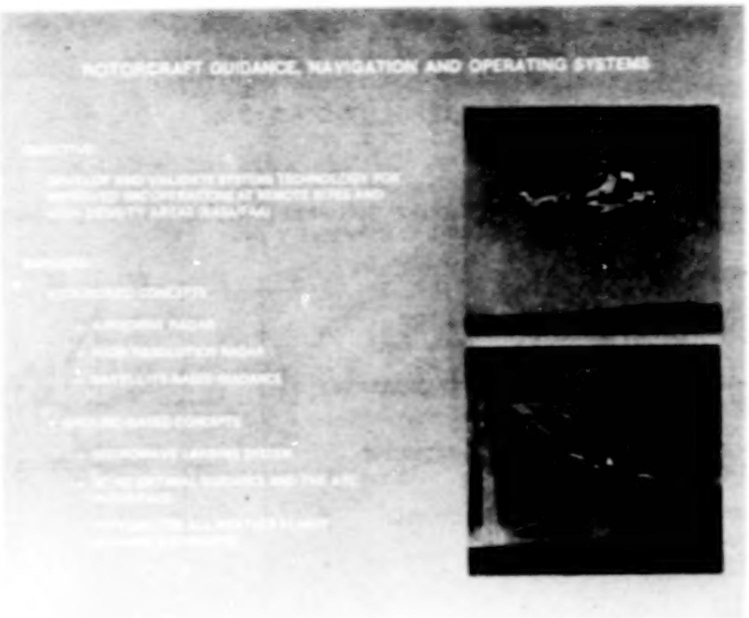


ROTORCRAFT GUIDANCE, NAVIGATION AND OPERATING SYSTEMS

OBJECTIVE:

- DEVELOP AND VALIDATE SYSTEM TECHNOLOGY FOR IMPROVED IMC OPERATIONS AT REMOTE SITES AND HIGH DENSITY AREAS (NASA/FAA)

APPROACH:

- AIRCRAFT-BASED CONCEPTS
  - AIRBORNE RADAR
  - HIGH RESOLUTION RADAR
  - SATELLITE-BASED GUIDANCE
- GROUND-BASED CONCEPTS
  - MICROWAVE LANDING SYSTEM
  - [illegible] GUIDANCE AND THE ATC [illegible]
  - [illegible] ALL WEATHER FLIGHT [illegible]

FIG. 1

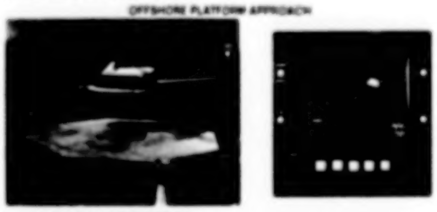
AIRBORNE RADAR

OBJECTIVE

- DEVELOP AND VALIDATE ENHANCED WEATHER RADAR GUIDANCE CONCEPTS FOR IMPROVED ROTORCRAFT IMC LANDING CAPABILITY

OVERWATER CONCEPTS

OFFSHORE PLATFORM APPROACH

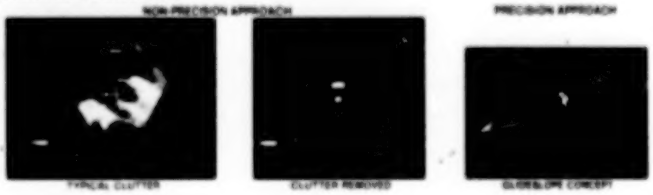


- COURSE GUIDANCE
- AUTOMATIC TRACKING
- AUTO GAIN AND TILT CONTROL

OVERLAND CONCEPTS

NON-PRECISION APPROACH

PRECISION APPROACH



TYPICAL CLUTTER

CLUTTER REMOVED

GLIDESLOPE CONCEPT

FIG. 2

HIGH RESOLUTION RADAR

OBJECTIVE:

- INVESTIGATE HIGH RESOLUTION RADAR GUIDANCE CONCEPTS FOR ROTORCRAFT "ONBOARD" ZERO VISIBILITY LANDING CAPABILITY

PROGRAM:

- HIGH RESOLUTION RADAR SIMULATION METHODOLOGY (HARVEY MUDD COLLEGE)
- CANDIDATE DISPLAY/CONTROL COMBINATIONS (BELL HELICOPTER)
- LANDING GUIDANCE IMAGE ENHANCEMENT (AMA AND UCD)
- RADAR CATEGORY IIIc LANDING SYSTEM PRELIMINARY DESIGN STUDY

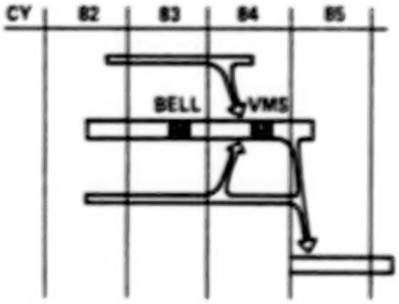


FIG. 3

NASA/AMES CIVIL HELICOPTER SATELLITE NAVIGATION

DIFFERENTIAL GPS TERMINAL GUIDANCE EXPERIMENTS

OBJECTIVE

EVALUATE DIFFERENTIAL GPS FOR CIVIL HELICOPTER PRECISION APPROACH

APPROACH

- STUDY ALTERNATE SYSTEM TYPES
- DEVELOP S/W ALGORITHMS/OPERATING PROCEDURES THROUGH SIMULATION
- DESIGN/FAB HARDWARE SYSTEMS FOR DIFFERENTIAL TESTING
- CONDUCT INFLIGHT EVALUATION OF DIFFERENTIAL GPS SYSTEM AND PROCEDURES

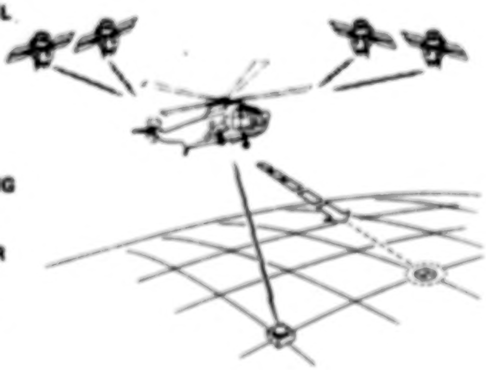


FIG. 4

GUIDANCE
MISSION REQUIREMENTS

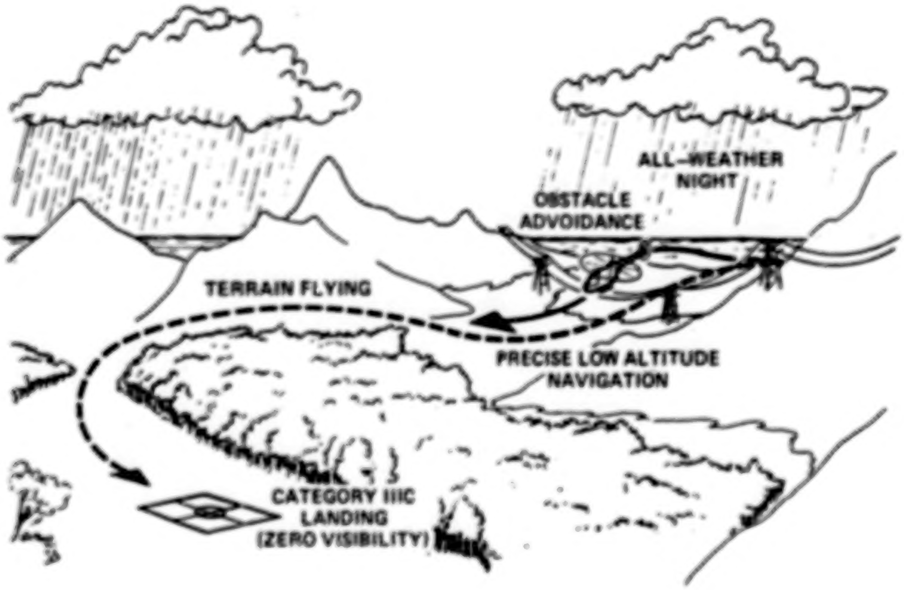

ALL-WEATHER
NIGHT
OBSTACLE
ADVOIDANCE
TERRAIN FLYING
PRECISE LOW ALTITUDE
NAVIGATION
CATEGORY IIIC
LANDING
(ZERO VISIBILITY)

FIG. 5

GUIDANCE

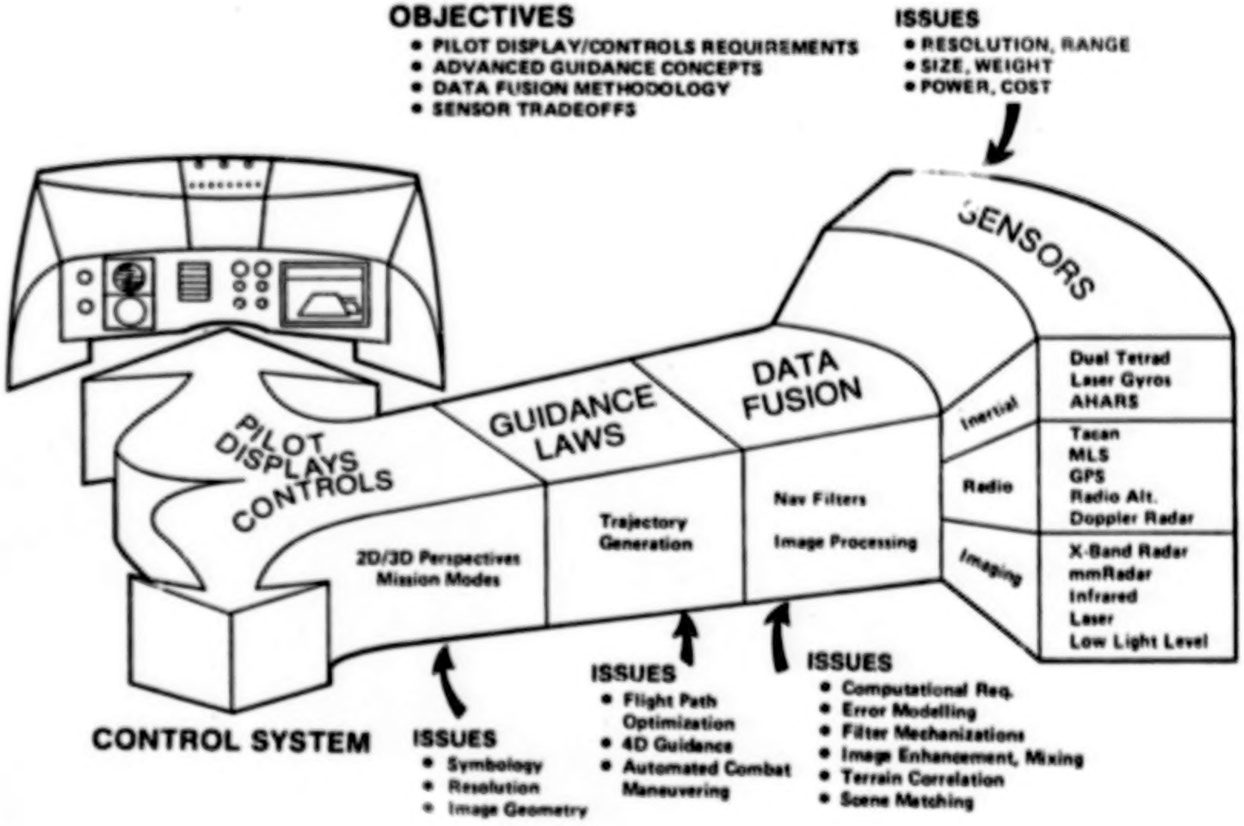

OBJECTIVES
• PILOT DISPLAY/CONTROLS REQUIREMENTS
• ADVANCED GUIDANCE CONCEPTS
• DATA FUSION METHODOLOGY
• SENSOR TRADEOFFS
ISSUES
• RESOLUTION, RANGE
• SIZE, WEIGHT
• POWER, COST
SENSORS
Inertial
Dual Tetrad
Laser Gyros
AHARS
Radio
Tacan
MLS
GPS
Radio Alt.
Doppler Radar
Imaging
X-Band Radar
mmRadar
Infrared
Laser
Low Light Level
DATA FUSION
Nav Filters
Image Processing
GUIDANCE LAWS
Trajectory Generation
PILOT DISPLAYS CONTROLS
2D/3D Perspectives
Mission Modes
CONTROL SYSTEM
ISSUES
• Symbology
• Resolution
• Image Geometry
ISSUES
• Flight Path Optimization
• 4D Guidance
• Automated Combat Maneuvering
ISSUES
• Computational Req.
• Error Modelling
• Filter Mechanizations
• Image Enhancement, Mixing
• Terrain Correlation
• Scene Matching

FIG. 6

INTEGRATING INTELLIGENCE

OBJECTIVES

- O PROVIDE THE INFORMATION REQUIRED FOR THE FUNCTIONAL DESIGN OF FULLY INTEGRATED FLIGHT GUIDANCE AND CONTROL SYSTEMS.
- O PROVIDE A BASELINE CAPABILITY FOR EVALUATING GUIDANCE, CONTROL, AND COCKPIT DIALOG CONCEPTS IN CONTEXT OF A TOTAL SYSTEM

ISSUES

- O OPTIMAL ALLOCATION OF TASKS
- O INTEGRATING INTELLIGENCE REQUIRED FOR FUNCTIONAL INTEGRATION
- O TECHNIQUES FOR ASSESSING PERFORMANCE

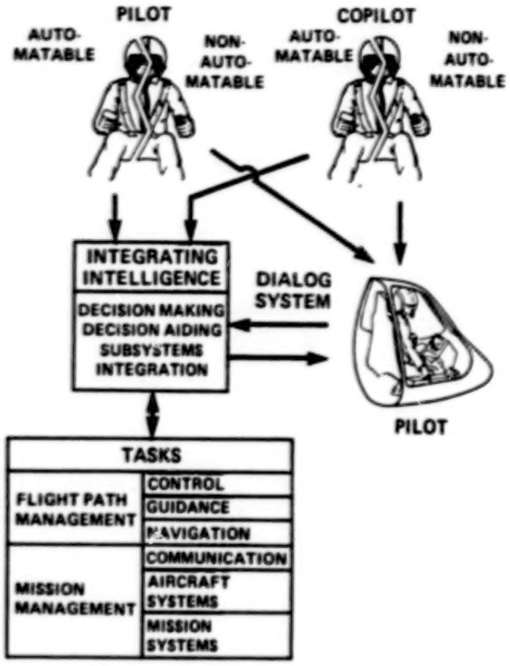

PILOT
AUTO-MATABLE
NON-AUTO-MATABLE
COPILOT
AUTO-MATABLE
NON-AUTO-MATABLE
INTEGRATING INTELLIGENCE
DECISION MAKING
DECISION AIDING
SUBSYSTEMS INTEGRATION
DIALOG SYSTEM
PILOT
TASKS
FLIGHT PATH MANAGEMENT
CONTROL
GUIDANCE
NAVIGATION
MISSION MANAGEMENT
COMMUNICATION
AIRCRAFT SYSTEMS
MISSION SYSTEMS

FIG. 7

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DEMONSTRATION ADVANCED AVIONICS SYSTEM

OBJECTIVE

PROVIDE THE INFORMATION REQUIRED FOR THE DESIGN OF FULLY INTEGRATED AVIONICS SUITABLE FOR GENERAL AVIATION IN THE 1980's AND BEYOND.

ISSUES

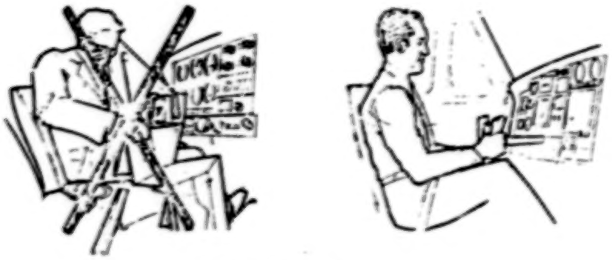
PILOT SYSTEM INTERFACE

- CAPABILITY
- SAFETY

ARCHITECTURAL DESIGN

- RELIABILITY
- MAINTAINABILITY
- MODULARITY
- COST

DAAS FUNCTIONAL CAPABILITIES



- GUIDANCE AND NAVIGATION
- FLIGHT CONTROLS
- FLIGHT STATUS
- COMPUTER ASSISTED HANDBOOK COMPUTATIONS
- MONITORING AND WARNING
- DATA LINK
- COMPUTER ASSISTED MAINTENANCE
- NORMAL AND EMERGENCY CHECKLISTS
- SIMULATION

FIG. 8

DAAS INSTRUMENT PANEL

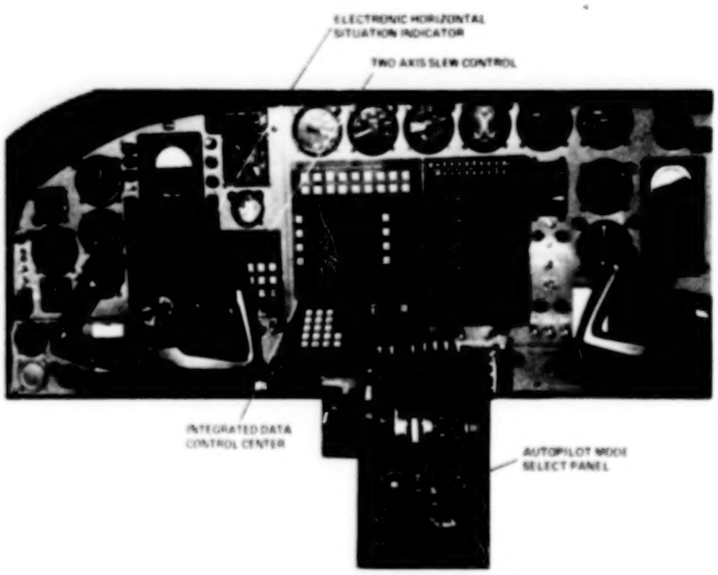

ELECTRONIC HORIZONTAL SITUATION INDICATOR
TWO AXIS SLEW CONTROL
INTEGRATED DATA CONTROL CENTER
AUTOPILOT MODE SELECT PANEL

FIG. 9

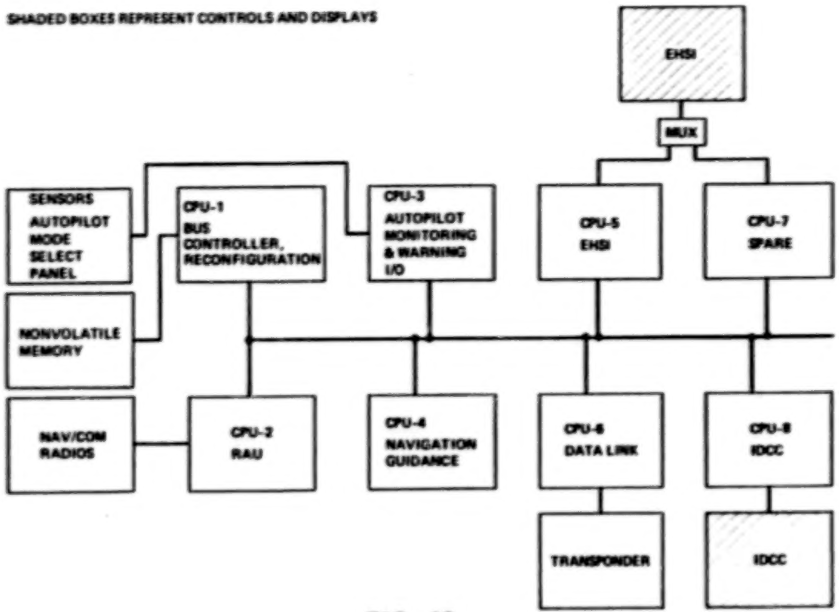

DAAS ARCHITECTURE
SHADED BOXES REPRESENT CONTROLS AND DISPLAYS
EHSI
MUX
SENSORS
AUTOPILOT MODE SELECT PANEL
CPU-1 BUS CONTROLLER, RECONFIGURATION
CPU-3 AUTOPILOT MONITORING & WARNING I/O
CPU-5 EHSI
CPU-7 SPARE
NONVOLATILE MEMORY
NAV/COM RADIOS
CPU-2 RAU
CPU-4 NAVIGATION GUIDANCE
CPU-6 DATA LINK
CPU-8 IDCC
TRANSPONDER
IDCC

FIG. 10

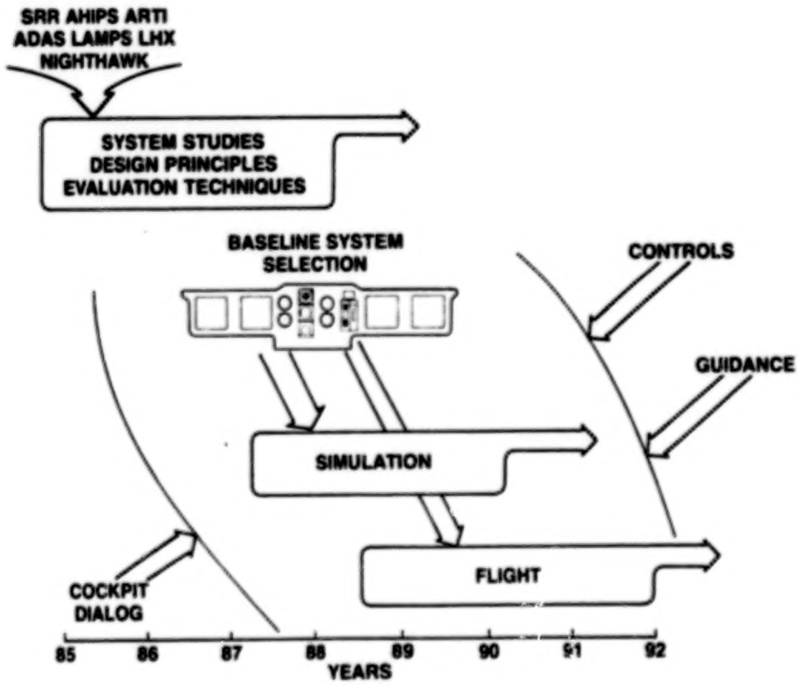

INTEGRATING INTELLIGENCE APPROACH
SRR AHIPS ARTI
ADAS LAMPS LHX
NIGHTHAWK
SYSTEM STUDIES
DESIGN PRINCIPLES
EVALUATION TECHNIQUES
BASELINE SYSTEM SELECTION
CONTROLS
GUIDANCE
SIMULATION
FLIGHT
COCKPIT DIALOG
85
86
87
88
89
90
91
92
YEARS

FIG. 11

SESSION 2

OPERATIONAL REQUIREMENTS FOR FUTURE HELICOPTERS

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N85 14810

D4

ARMY AVIATION TODAY AND TOMORROW

Major George Philips

US Army Aviation Center
Fort Rucker, Alabama

STRIVE FOR EXCELLENCE
ABOVE THE BEST
USAAVNC

Greetings.

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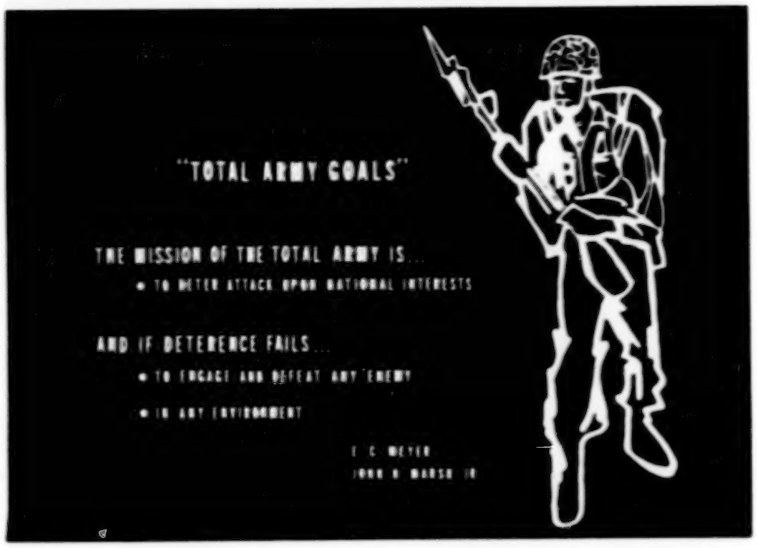

"TOTAL ARMY GOALS"

THE MISSION OF THE TOTAL ARMY IS...

- TO DETER ATTACK UPON NATIONAL INTERESTS

AND IF DETERENCE FAILS...

- TO ENGAGE AND DEFEAT ANY ENEMY
- IN ANY ENVIRONMENT

E. C. MEYER
JOHN O. MARSH JR

ARMY AVIATION

MISSION

CSA NOV 81..."TO CONDUCT PROMPT AND SUSTAINED COMBAT OPERATIONS"

The mission of Army Aviation is to conduct prompt and sustained combat operations. We must, therefore, be prepared to deter, fight, and win at anytime and anyplace.

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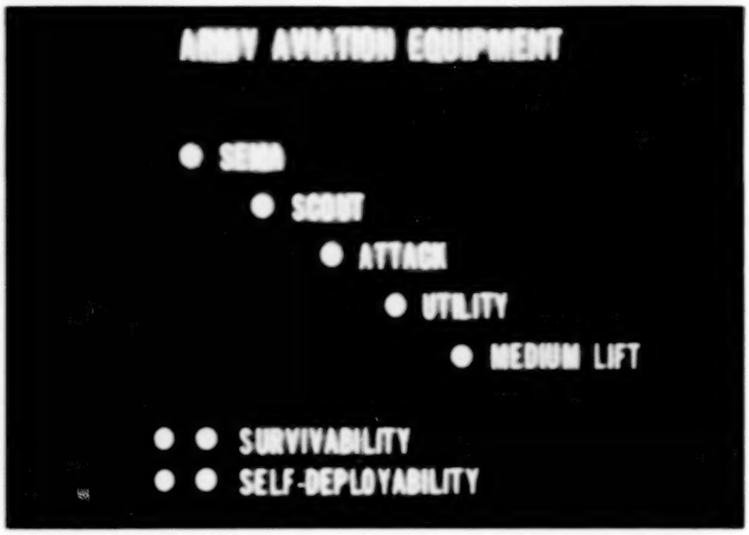

ARMY AVIATION EQUIPMENT

- SEMA
- SCOUT
- ATTACK
- UTILITY
- MEDIUM LIFT

- SURVIVABILITY
- SELF-DEPLOYABILITY

We can start by discussing our present aircraft.

SPECIAL ELECTRONICS MISSION AIRCRAFT

GUARDRAIL
QUICK FIX
QUICK LOOK
SLAR

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First, our Special Electronics Mission Aircraft, or SEMA. This fleet consists of the RC-12 Guardrail, the RV-1 Quick Look, and the OV-1 Side Looking Airborne Radar. These systems enable the Corps Commander to see the Battlefield, disrupt enemy electronics communications far beyond the flot, and concentrate his forces at the right time and place. Near fielding is the EH-60 Quick Fix--the first true division-level electronic warfare system. These aircraft are all programmed to be replaced by one aerial platform, the SEMA-X, during the 1992 to 2000 time frame.

Whereas SEMA allows us to see deep, the Aeroscout's mission is to see the close-in battlefield, acquire targets, and coordinate movement of attack helicopters. He acts as the eyes and ears of the Commander and is the attack team battle captain.

ARMY HELICOPTER IMPROVEMENT PROGRAM
OH-58D AEROSCOUT

The Army Helicopter Improvement Program, or AHIP, is being developed to improve the Aeroscout's capabilities to work with attack helicopters, field artillery, and Air Force aircraft. The AHIP Scout will be a modified OH-58 equipped with a mast-mounted sight, digital avionics and CRT displays, and provisions for an air-to-air missile system.

The day/night, mast-mounted target acquisition and laser designator system on the AHIP Scout is the prototype of a system that will rpovide the Aeroscout with the capability to remain partially masked while performing reconnaissance, surveillance, target acquisition, and target designation. It is capable of acquiring targets out to ranges compatible with attack helicopter systems.

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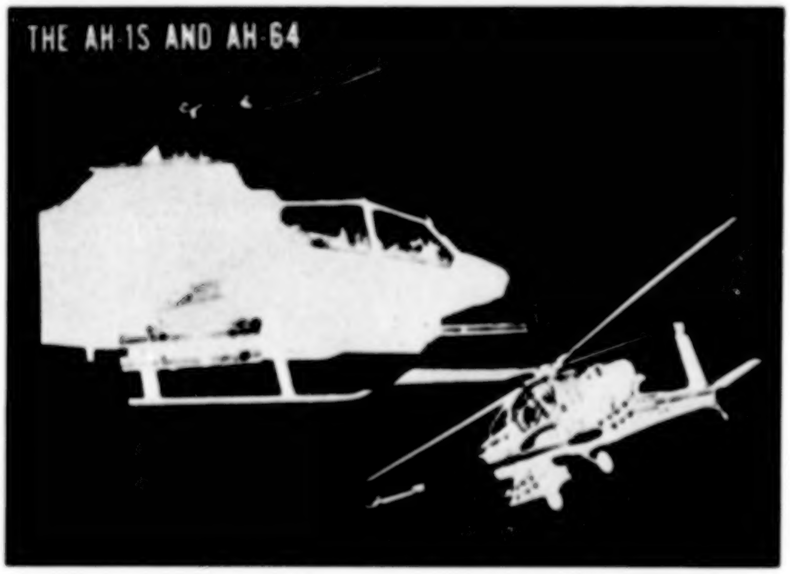
A far term program will initiate a series of advanced technological improvements that will lead to a light family of helicopters, or LHX. The LHX, possibly in one of these configurations, could be equipped for either a Scout, Attack, or Utility mission. LHX is summed up on this slide.

ADVANCED SCOUT HELICOPTER

LHX CONCEPT

While the Scout serves as the eyes and ears of the Commander, the unique fire and maneuver capability of the Attack helicopter allows the Commander to deny and dominate key terrain on the battlefield.



THE AH-1S AND AH-64

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The "Armed" Helicopter was born of the need to provide armed escort and supporting fires for troop carriers. "Attack" helicopters were a logical follow-on. As we enter the 1980's, we have two new and remarkable aircraft, the AH-1S fully modernized Cobra and the AH-64 Advanced Attack Helicopter.

THE ATTACK HELICOPTER
AH-1S MODERNIZED COBRA

The AH-1S fully modernized Cobra currently being fielded will be an integral part of the Amry's Attack Helicopter Force through the year 2000. In the European environment, this Cobra can carry eight TOW missiles for use against armored or point targets at ranges of up to 3,750 meters and 320 rounds of 20mm ammunition for use against lightly armored targets out to a range of 2,000 meters. The TOW missile is being improved to have a shorter time of flight from launch to impact and greater lethality.

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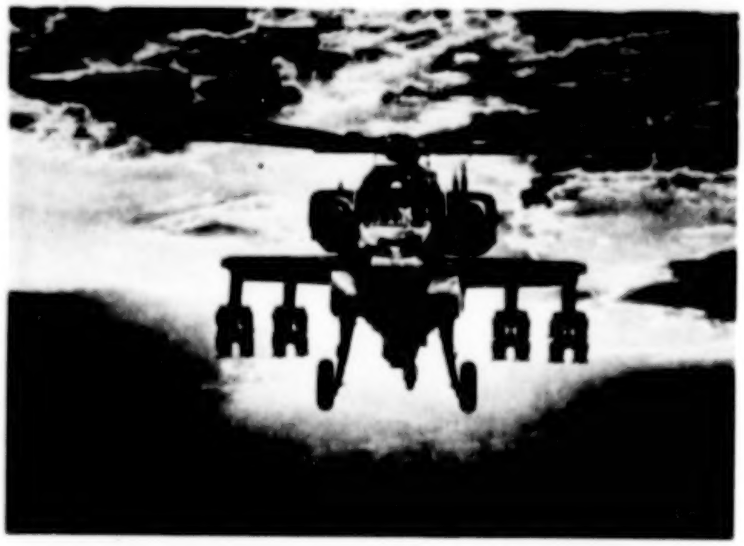
For area targets, the aircraft can carry up to seventy-six 70mm rockets which have the flexibility of delivering high explosive, illumination, and multipurpose submunitions. The 20mm cannon may also be used against area targets or aircraft, thin-skinned vehicles, and personnel.

We continue to explore means of providing the AH-1 with a night-fight capability.

THE ATTACK HELICOPTER

The AH-64 Apache, our advanced attack helicopter, will further improve the Army's capability to influence the battle over a broad front.



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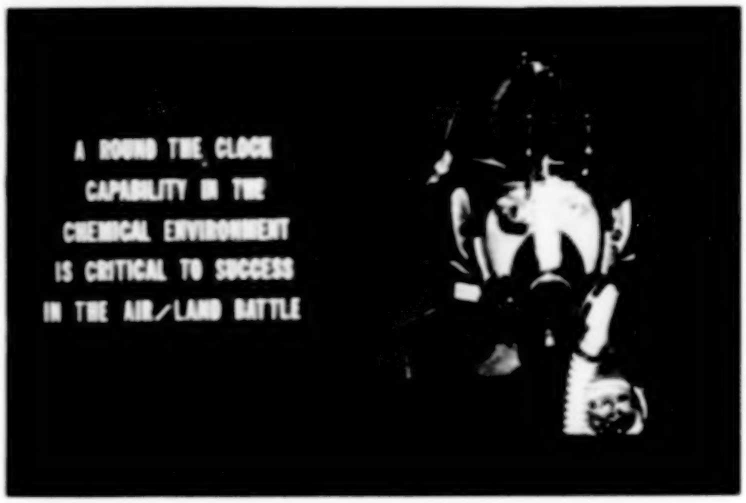
The AH-64 can carry as many as 16 HELLFIRE missiles. The HELLFIRE's range is up to 8 kilometers, and it is capable of destroying all known and projected armor. The 30mm Chain Gun fires a high explosive, armor-piercing round out to 3 kilometers. The AH-64 can also be armed with 70mm rockets. The helmet display unit interfaces with the pilot night vision system and shows attitude, heading, power, airspeed, and altitude.



A ROUND THE CLOCK
CAPABILITY IN THE
CHEMICAL ENVIRONMENT
IS CRITICAL TO SUCCESS
IN THE AIR/LAND BATTLE

The Target Acquisition and Designation System enables the crew to find and destroy targets during day, night, obscuration, and adverse weather conditions.

UTILITY AND CARGO TRANSPORT
UH-1 UH-60 CH-47

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One of the primary functions of the helicopter is to give the ground commander the ability to rapidly move his forces about the battlefield. Integrated into the combined arms team, assault helicopter forces provide an excellent means for the Commander to exploit assailable flanks before the enemy is able to reposition and fill gaps in his defenses. Operating throughout the battle area, assault forces can strike when, where, and in a manner the enemy least expects it.

In the 1980 to 1990 time frame, we will have the UH-1, UH-60, and CH-47 for air mobility and air assault.

UTILITY HELICOPTER
UH-1

Requirements exist to retain approximately 2,700 UH-1 aircraft in service at least though the year 2000.

UTILITY HELICOPTER
UH-60

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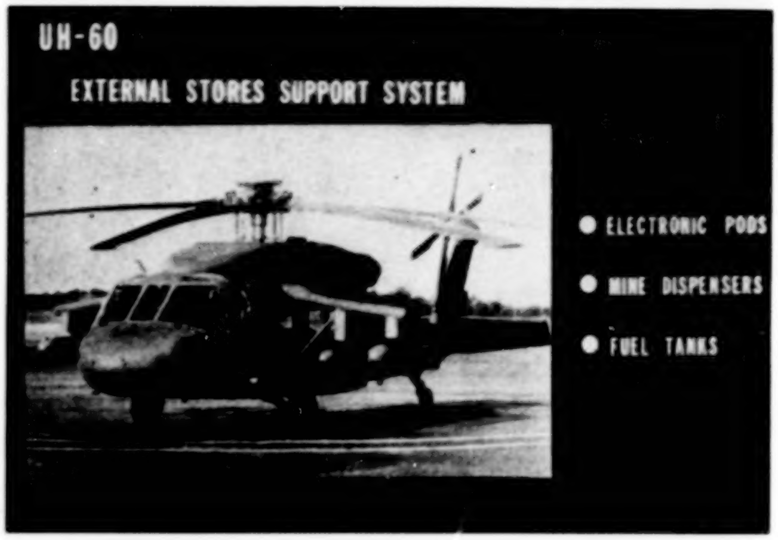
The UH-60 Black Hawk is the Army's first line utility assault helicopter. It is adaptable to all intensities of conflict and has great productivity. For example, it will replace the Huey on a two-for-three basis in combat aviation companies, replacing 23 UH-1's with only 15 UH-60's.

The Black Hawk will be used primarily in the main battle area as a squad carrier and logistics aircraft. It will be organic to combat support aviation companies and air cavalry troops. The UH-60 will enable the Ground Commander to make the offensive a viable option by rapid movement of assault forces and antiarmor teams, rapid resupply throughout the battle area, and rapid deployment of rear area security forces in response to enemy airborne or air mobile operations.



UH-60

EXTERNAL STORES SUPPORT SYSTEM

- ● ELECTRONIC PODS
- ● MINE DISPENSERS
- ● FUEL TANKS

Additionally, we are developing an External Stores Support System for electronics, mines, and fuel pods. This will enhance UH-60 mission flexibility, aircraft utility, and self-deployability.

CH-47

COMBAT SUPPORT

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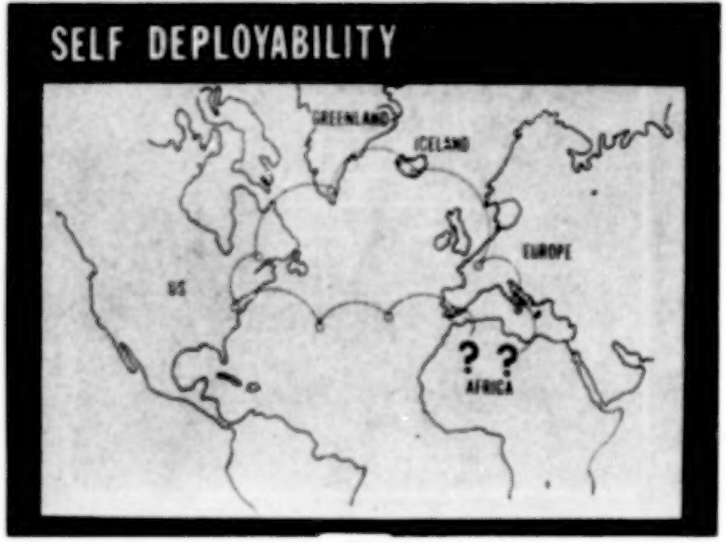
The CH-47 Chinook is our combat-proven medium lift helicopter. An ongoing modernization program will provide an improved medium lift helicopter known as the CH-47D.

MEDIUM LIFT HELICOPTER
CH-47D
5
UNITED STATES ARMY

Seven major modifications will be made to the CH-47 on its way to becoming a "D" model. These include fiberglass rotor blades, more powerful engines, and updated transmissions--improved hydraulic, electrical, and flight control systems--and a triple hook suspension. On a standard day, the "D" model can lift 33 troops or 25,000 pounds (12,000 kilos) of internal or external cargo.

Cargo and utility helicopters will play a vital role on the integrated and extended airland battlefield, particularly in the conduct of high priority tactical airlift to maneuver forces that will be widely dispersed to avoid becoming potential nuclear or chemical targets.


SELF DEPLOYABILITY
GREENLAND
ICELAND
EUROPE
US
? ?
AFRICA

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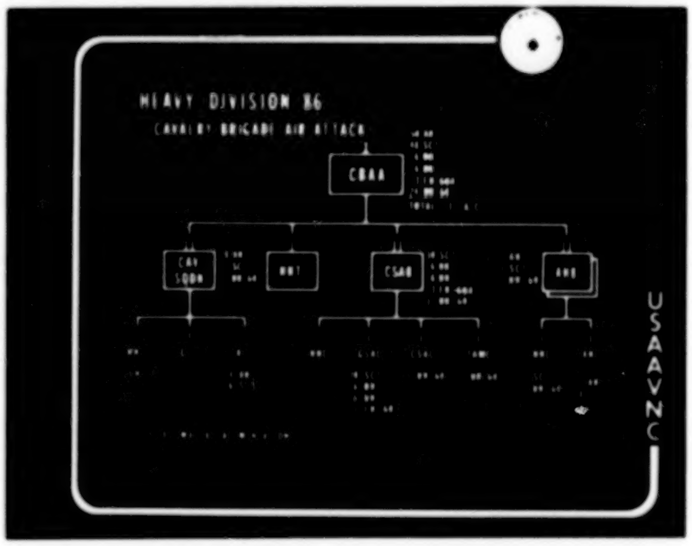
A great many of the Aircraft I have just discussed will be aviation assets based in the Continental United States. That, coupled with requirements to reinforce NATO, has prompted the Army to approve the self-deployability concept for selected Army aircraft.

HELICOPTER SELF-DEPLOYMENT
ATTACK...ASSAULT...SUPPORT

Therefore, we are pursuing the development of internal and external fuel systems and navigational devices that will provide the UH-60, AH-64, and Ch-47 with the capability to self-deploy to any battlefield. And of equal importance, this equipment will provide these aircraft with a capability to do missions requiring extended range on the battlefield.

The Army Aviation Organization of the future is the Cavalry Brigade (Air Attack).



HEAVY DIVISION 86
CAVALRY BRIGADE AIR ATTACK

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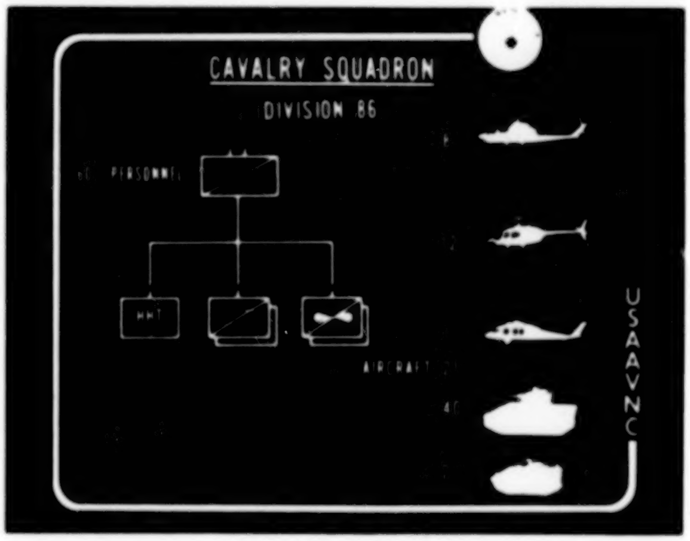
This is what the heavy division for 1986 will look like. Please note that all the aviation assets of the division are organized under the Cavalry Brigade (Air Attack). The Brigade was conceived to optimize employment of all the new aviation equipment being introduced and provide the division commander additional tactical flexibility.

THE CAVALRY BRIGADE (AIR ATTACK)

This is the CBAA Organization for the heavy division. It is a highly mobile and flexible force of some 1,834 personnel and 137 aircraft organized into a brigade headquarters, a cavalry squadron, a combat support aviation battalion, and two attack helicopter battalions.


CAVALRY SQUADRON
DIVISION 86
PERSONNEL
HHT
AIRCRAFT
40
USAAVNC

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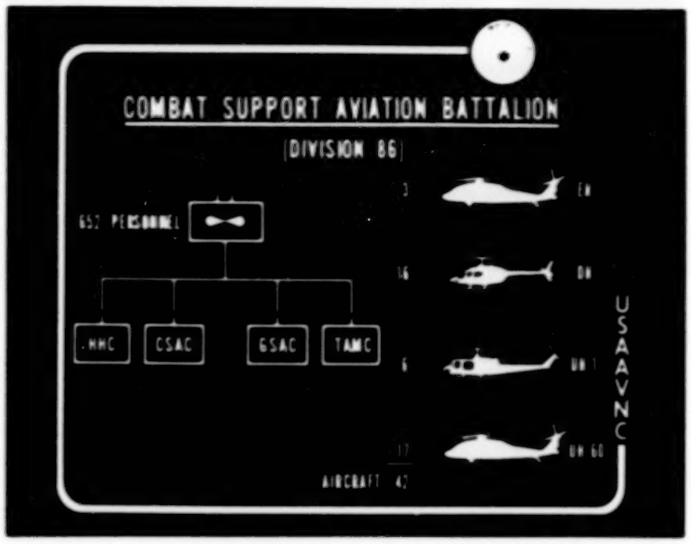
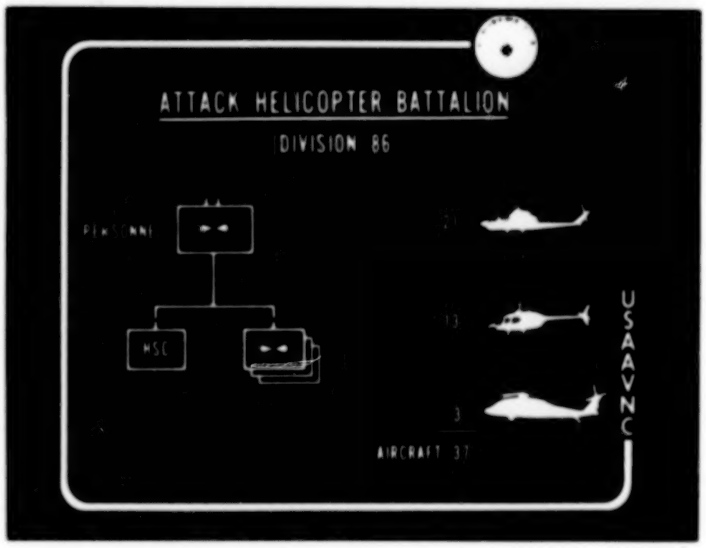
The 585-Man Cavalry Squadron, armed with both aircraft and ground fighting vehicles, has been designed based on an operational concept that stresses reconnaissance within, to the front, on the flanks, and to the rear of the division.


COMBAT SUPPORT AVIATION BATTALION
(DIVISION 86)
652 PERSONNEL
HHC
CSAC
GSAC
TAMC
3
EH
16
OH
6
UH 1
17
UH 60
AIRCRAFT 42
USAAVNC

The Combat Support Aviation Battalion of 605 personnel, equipped with 42 aircraft, furnishes general aviation support to the division. It provides forward observer aircraft, command and control aircraft, special electronics mission aircraft, a combat support aviation company equipped with 15 UH 60's, and the aircraft maintenance company for the brigade.


ATTACK HELICOPTER BATTALION
(DIVISION 86
PERSONNEL
HSC
21
13
3
AIRCRAFT 37
USAAVNC

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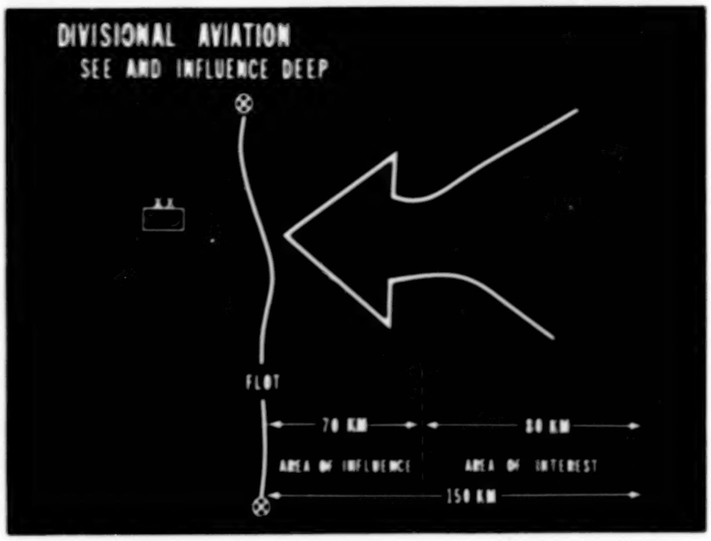
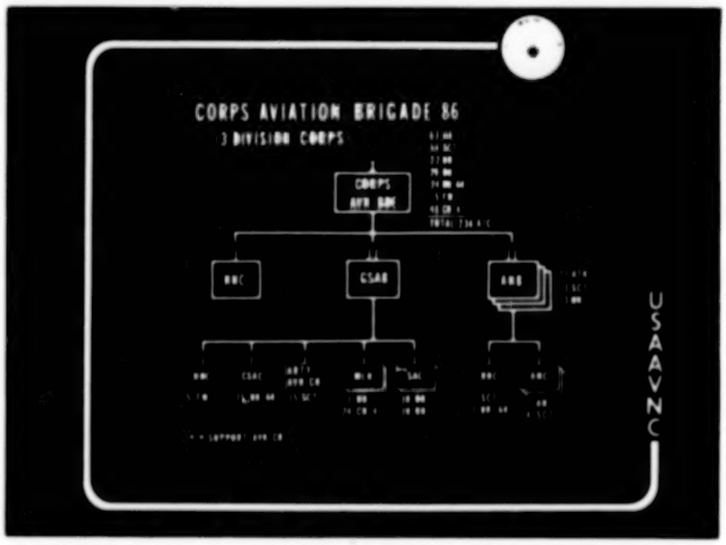
The attack battalions with 271 personnel and 37 aircraft each are the tank killing elements of the brigade, providing the flexibility required to conduct multiple attack missions. The attack helicopter battalions also offer may capabilities and advantages for a rapid deployment force. For example, our attack helicopters will be capable of either self-deploying or being airlifted to the area of operations where they can provide highly mobile firepower capable of defeating all known armor.



DIVISIONAL AVIATION
SEE AND INFLUENCE DEEP

FLOT
70 KM
80 KM
AREA OF INFLUENCE
AREA OF INTEREST
150 KM

As I have said previously, all aviation assets of the division will be located in one brigade. This aviation maneuver force enhances the Division Commander's ability to attain his doctrinal planning goals--to be able to see 150 kilometers beyond the forward line of own troops and to attack out to 70 kilometers in any direction.



CORPS AVIATION BRIGADE 86
(3 DIVISION CORPS)

CORPS AVN BDE
TOTAL 736 A/C
HHC
GSAB
AHB
HHC
CSAC
ARTY AVN CO
HHC
AHC
SUPPORT AVN CO
USAAVNC

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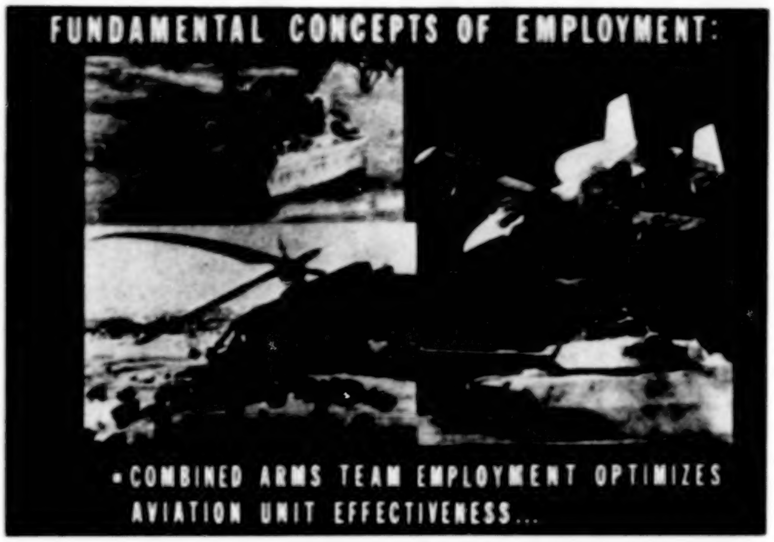
Shown here is the Corps aviation brigade for a Three-Division Corps. The significant difference between this organization and the divisional brigade is the addition of two medium lift companies and an Attack Helicopter Battalion.



FUNDAMENTAL CONCEPTS OF EMPLOYMENT:

- COMBINED ARMS TEAM EMPLOYMENT OPTIMIZES AVIATION UNIT EFFECTIVENESS...

Vietnam provided us with valuable lessons on the employment of aviation forces on the battlefield. To capitalize on these lessons and to determine the best techniques to use in future airland battles, we have conducted numerous exercises. Several fundamental concepts have emerged as a result of these exercises. They are:

Combined air and ground team employment optimizes attack helicopter effectiveness.

FUNDAMENTAL CONCEPTS OF EMPLOYMENT:

- NAP-OF-THE-EARTH IS ESSENTIAL ...

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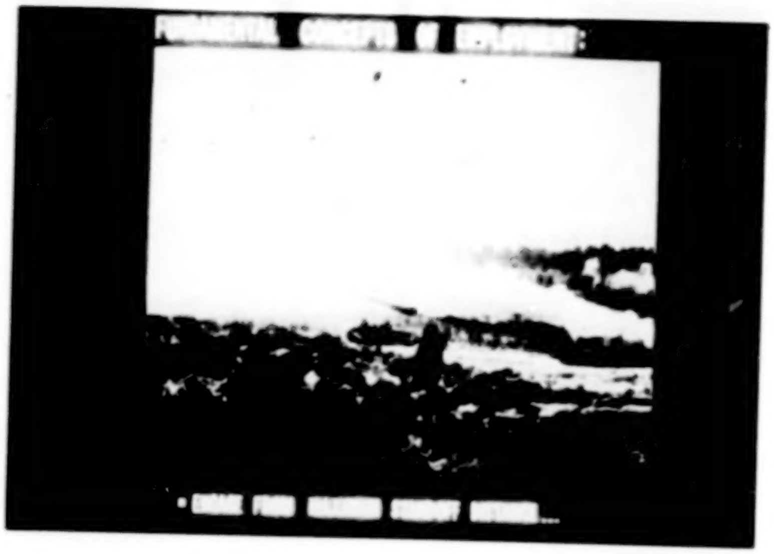
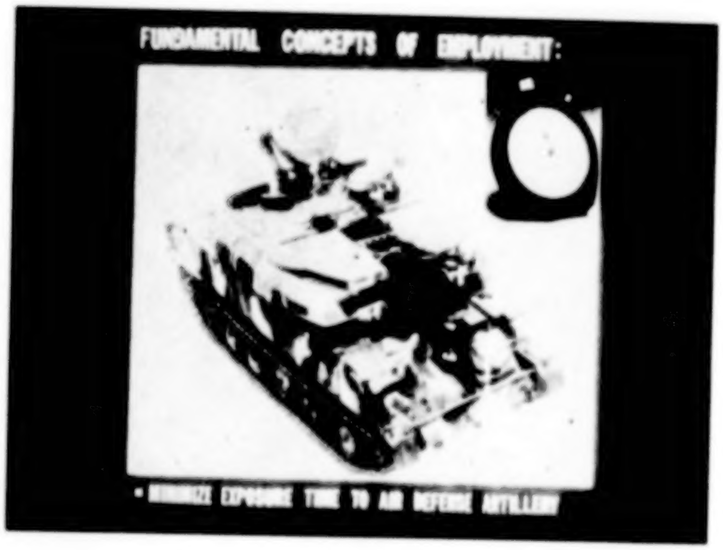
Nap-of-the-earth terrain; flying is essential.



FUNDAMENTAL CONCEPTS OF EMPLOYMENT:

- ENGAGE FROM MAXIMUM STANDOFF DISTANCE...

Engaging from maximum standoff distance is a must.



FUNDAMENTAL CONCEPTS OF EMPLOYMENT:

- MINIMIZE EXPOSURE TIME TO AIR DEFENSE ARTILLERY

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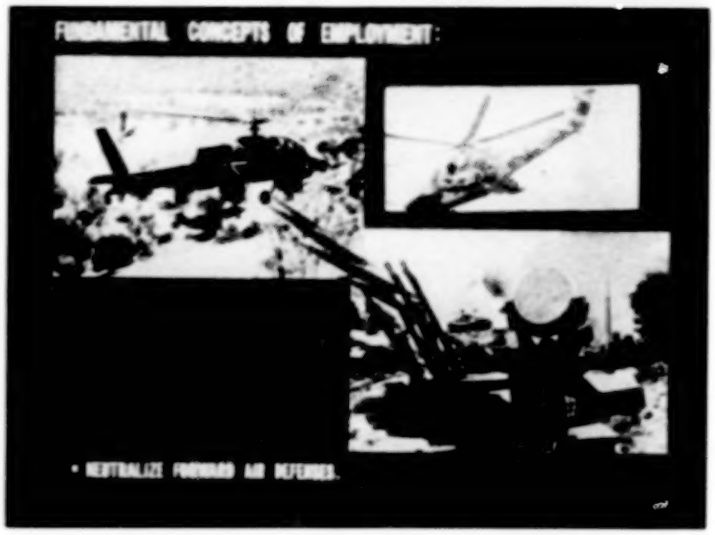
Minimizing exposure time to treat air defense artillery is a requirement.



FUNDAMENTAL CONCEPTS OF EMPLOYMENT:

- NEUTRALIZE FORWARD AIR DEFENSES.

And, we must neutralize forward air defenses--both ground and air.

ARMY AVIATION

A COMBAT ARM

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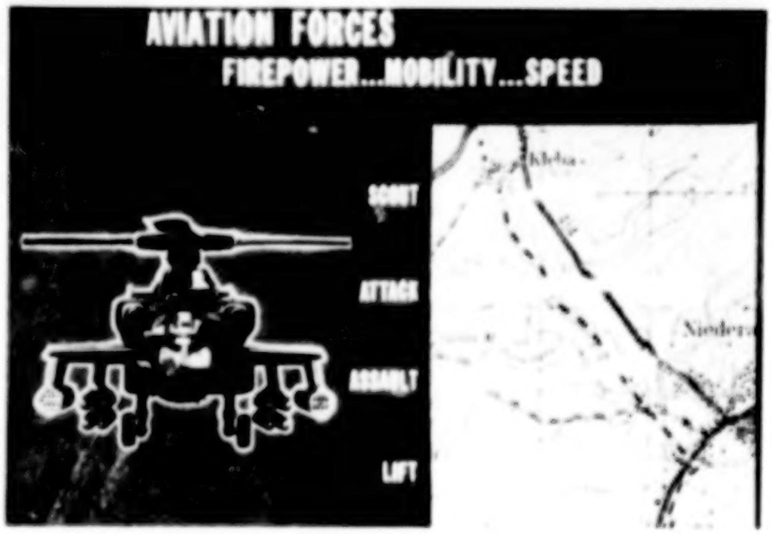
As a member of the combined arms team, Army Aviation will develop these concepts to their fullest extent. (Note: Aviation is a branch).

ARMY COMBAT EFFECTIVENESS

DEPENDS ON COMBINED ARMS OPERATIONS

The latest doctrine, coupled with new equipment and a totally professional force, will result in greater combat effectiveness.



AVIATION FORCES

FIREPOWER...MOBILITY...SPEED

SCOUT

ATTACK

ASSAULT

LIFT

In conclusion. Aviation has evolved dramatically since its beginning in 1942. From a limited role of observing artillery fire. To a full-fledged member of the combined arms team. While it is impossible to see the future, we believe that our aviation forces will significantly influence the outcome of tomorrow's battles. As a result, we are moving ahead in the direction I have just described.

Gentlemen...That concludes my briefing.

D5

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MARINE HELICOPTER MISSIONS

Major Steve Hill, U.S.M.C.

Marine Corps Base
H&MS-39, MAG-39
Camp Pendleton, CA

There are four different helicopters in the Marine Corps inventory and the mission of each is the subject of this presentation.

The first type is found in the Marine Heavy Helicopter Squadron and is Sikorsky's CH-53. Marines fly the A and D models and the new CH-53E shown in the following slides.

MARINE HEAVY
HELICOPTER SQUADRON

The mission of the CH-53 is to provide helicopter transport of supplies, equipment, and personnel.

HMH (CH-53)

Mission –

Provide helicopter transport of supplies, equipment, and personnel

Although the CH-53 is well-suited to transport troops, its primary task is to transport supplies and equipment.

PRIMARY TASK OF HMH

Transporting Supplies and Equipment

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The Marine Medium Helicopter Squadron is the organization that maintains the CH-46. Marines are currently flying the D and E models of this Boeing product.

MARINE MEDIUM HELICOPTER SQUADRON

Here are some CH-46's in their shipboard configuration.

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Here are the tasks of the CH-46.

TASKS

- **Transport**
- **Evacuation**
- **SAR**
- **Shipboard Operations**
- **Night and IFR**
- **Organizational Maintenance**

While the CH-46 is well capable of carrying supplies and equipment (it often does), it's primary task is to transport troops.

PRIMARY TASK OF HMM

— Transporting Marines —

The third type helicopter is found in the Marine Light Helicopter Squadron. It is UH-1N which is the military version of the Bell 212.

MARINE LIGHT HELICOPTER SQUADRON

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This shows the left ride of a huey that is configured for medevac. Notice on the right side a hoisting device which is also found on the CH-46 and CH-53.

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These next slides shows how a huey is used to insert a reconnaissance team that will rappel to the ground.

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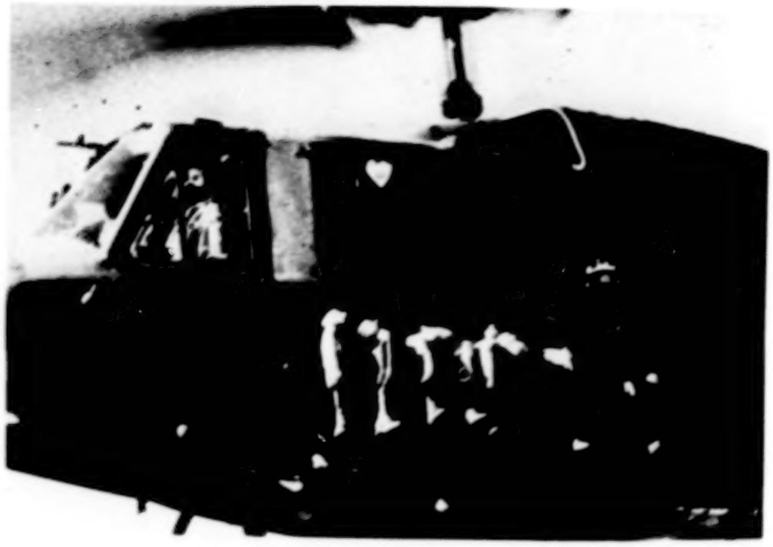

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The following slides show some paint schemes that have found to be effective.

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This shows an armed version of the huey with 7.62 miniguns and 2.75 in. rockets.

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The mission of the UH-1 is to provide utility helicopter support to the landing force during an amphibious landing, and for subsequent operations ashore.

HML (UH-1)

Mission –

Provide utility combat helicopter support

The tasks of the huey are shown here.

TASKS

- **Emerg Supply**
- **Casualty Evacuation**
- **Airborne Control of TACAIR**
- **Liaison/Courier**
- **SAR**
- **Spraying**
- **Wire Laying**
- **Organizational Maintenance**
- **Shipboard Operations**
- **Night and IFR**

Finally there is the Marine Attack Helicopter Squadron which flies the Bell AH-1 in the J and T models.

MARINE ATTACK
HELICOPTER SQUADRON

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Shown here is the AH-1T which is configured to fire the TOW missle.

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This is a nose-on view of an AH-1J which has a mission of escort.

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The mission of the AH-1 is shown here.

HMA (AH-1)

Mission –

Provide close-in fire support and fire support coordination in aerial and ground escort operations

Its tasks are shown in this slide.

TASKS

- Armed Escort for Helo's
- LZ Suppression
- Recon
- Target Marking
- Escort/Suppression for Ground Units
- Shipboard Operations
- Anti Armor
- FAC (A)/TAC (A)
- Night and IFR
- Organizational Maintenance

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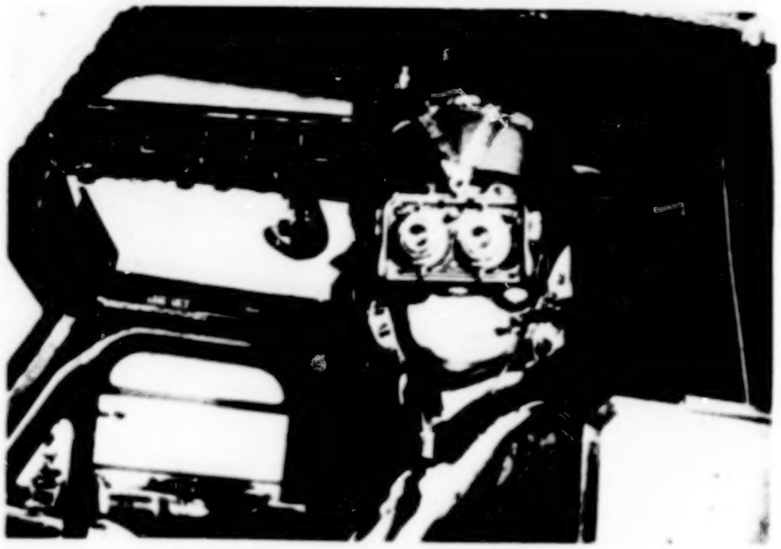
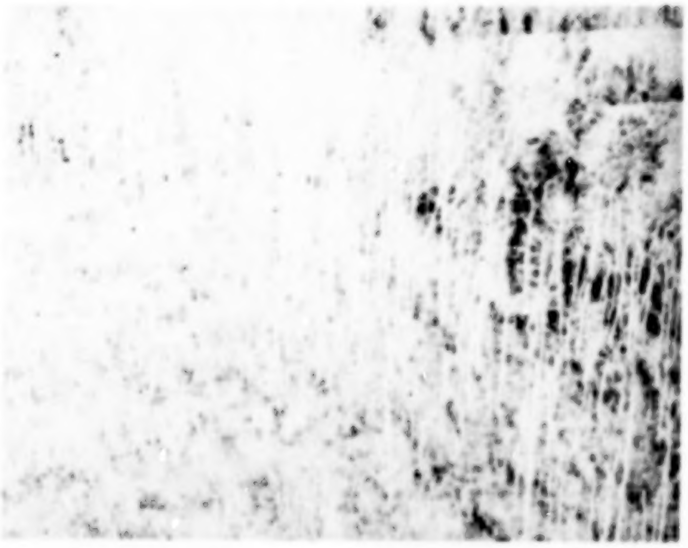
In order to operate more effectively at night we have adopted the use of night vision goggles. This shows a scene as it is normally viewed during daylight.





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This shows the same scene as it is viewed at night though the goggles.

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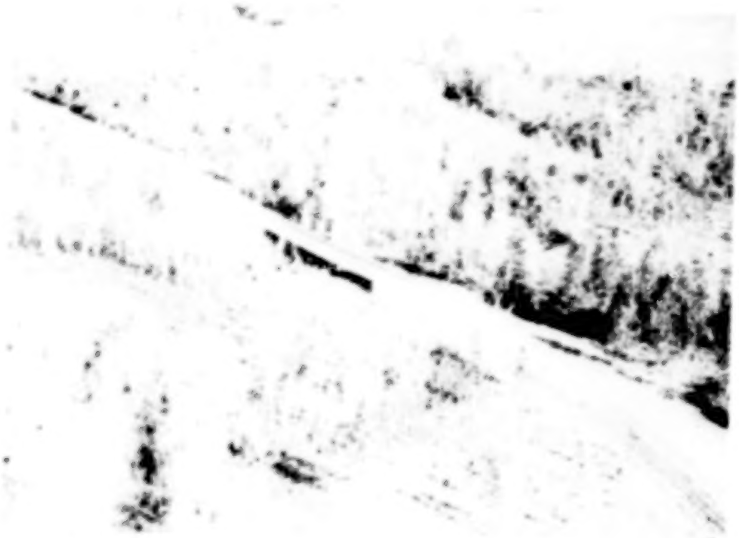
Here is another example.



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Similarities exist between the use of helicopters by the Marine Corps and their use by the Army. A significant departure from these similarities is the Marines concern with shipboard operations and the ship-to-shore movement.

D6

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CIVIL LAW ENFORCEMENT MISSIONS

LT. Robert M. Morrison

Huntington Beach Police Department
Huntington Beach, CA

As President of the Airborne Law Enforcement Association, I would like to present to you this morning the needs of public service helicopter operators when addressing the issue of future helicopter cockpit designs.

The Airborne Law Enforcement Association is a national and international association made up from public service agencies in law enforcement, fire departments, paramedic, rescue, conservation and federal government agencies who daily use helicopters as a routine part of their operations. From a historical standpoint, we could be considered the "new kid on the block" when it comes to helicopter operations, since our initial operations on a full-time basis started approximately 15 years ago. But, we are growing and have reached the point that public service should be considered as a viable part of the marketplace.

In 1970, there were 61 law enforcement agencies in the United States employing 118 aircraft. In ten years, those figures had risen to over 335 law enforcement agencies utilizing over 1,100 aircraft (both fixed wing and rotor craft).

In July of 1980, Mr. Tom Stuelpnagel, retired President of Hughes Helicopters, addressed a workshop meeting of public service operators here at Ames, and stated that public service operators comprise one-sixth of the total number of helicopters flying in the United States and account for as much as one-third of the civil flight hours.

To further illustrate this point, I recently completed a telephone survey of public service operators here in the State of California, and found that there are 32 agencies, city, county, state and federal, who are using a total of 128 helicopters that flew 97,892 hours in calendar year 1982.

PUBLIC SERVICE AIRCRAFT OPERATIONS

STATE OF CALIFORNIA

1982

32 AGENCIES

HELICOPTERS	128	97,892 hours
FIXED WING	70	31,622
	198	129,514
PILOT/CREW MEMBERS	488	
SUPPORT PERSONNEL	179	
	667	

Public service helicopter utilization covers a broad spectrum of use and our mission can quickly change on the basis of a single radio call. For example: We can be on routine police patrol over a metropolitan city and receive a call of the need for rescue services or the transportation of a SWAT team or a fire-fighting team. The mission can change from routine to complex very quickly and we try to be prepared to meet all demands, if we can afford them.

WHAT ARE THE PUBLIC SERVICE HELICOPTER USES?

o ENVIRONMENTAL CONTROL

A. WILDLIFE MANAGEMENT:
  1. Herding Animals
  2. Tagging Animals
  3. Relocating Animals
  4. Damage Control
  5. Fish Stocking
  6. Fish Management
  7. Spraying Insecticide

B. SURVEYS:
  1. Animal & Fish Population
  2. Inspect Oil Platforms
  3. Inspect Strip Mines
  4. Inspect Power Lines
  5. Inspect Dams & Reservoirs
  6. Aerial Photography
  7. Factory Pollution Monitoring
  8. Wetlands Inspection

C. EXTERNAL LOADS:
  1. Tower & Pole Setting
  2. Wire Stringing
  3. Pipeline Laying
  4. Liming Lakes
  5. Seeding Forests
  6. Remote Site Construction
  7. Remote Site Supply
  8. Shooding

D. LAND MANAGEMENT:
  1. Fire Control
    a. Bureau of Land Management
    b. U.S. Forest Service
    c. Bureau of Indian Affairs
  2. Geological Studies
    a. Exploration
    b. Earthquake Research
    c. Volcano Research
    d. Chaparel Monitoring
  3. Cadastral Surveys
  4. Electronic Surveys
  5. Resource Management

E. TRANSPORTATION
  1. Inspection
  2. Work Crews
  3. Survey Equipment
  4. Survey Personnel
  5. Resupply
  6. Search & Rescue

o FIRE FIGHTING

A. TRANSPORT PERSONNEL:
  1. Fire Crews
  2. Command Post
  3. Firefighting Tools, Hardware, & Supplies
  4. Suspended Maneuvering System

B. RETARDENT APPLICATIONS

C. RECONNAISSANCE
  1. Mapping
  2. IR Sensing
  3. Dry Season Surveillance

D. BACKFIRING

o DISASTER RELIEF

A. LIFESAVING PEOPLE TRANSPORT

B. LIFE SUSTAINING SUPPLY TRANSPORT

C. EVACUATION

D. EARLY WARNING & RESPONSE

E. COMMAND POST

F. POST DISASTER CLEAN-UP

WHAT ARE THE PUBLIC SERVICE HELICOPTER USES?

- LAW ENFORCEMENT & PUBLIC SAFETY

A. LAW ENFORCEMENT:

1. Drug Enforcement & Detection
2. Security (Buildings & VIPs)
3. Surveillance (General & Covert)
4. Search (Fugitives & Vehicles)
5. Patrol
6. Observation Post
7. High Speed Pursuit
8. Command Post
9. Crowd Control (Traffic & Riots)
10. Pollution Control
11. Transport (VIPs & Crime Specialists)

B. PUBLIC SAFETY:

1. Ambulance Escort
2. Disaster Warning & Relief
3. Emergency Cargo Transport
4. Fire Detection
5. Rescue
6. Search (People Lost)
7. Traffic (Emergency)
8. Water Area Patrol
9. Aerial Photography

- MEDICAL SERVICES

A. EMERGENCY MEDICAL SERVICES:

1. At the Scene Accident Pick-Ups
    a. Traffic
    b. Occupational
    c. Residential
    d. Recreational

2. Interhospital Transfers

    a. Critical Patient Transfer
    b. Neonatal Transfer
    c. Burn Patient Transfer
    d. Organ/Blood Transport
    e. Medical Supply Transport
    f. Medical Equipment Transport

B. SEARCH AND RESCUE:

1. Mountain Remote Site Rescue
2. Ocean/River Rescue
3. Missing or Late Vessels
4. Ship Collisions and Groundings
5. Missing Persons
6. Stolen Property Recovery
7. Aircraft Accidents
8. Endangered Fire Fighting Personnel

I would like to quickly present a potpourri of 35mm slides that will give you a visual assessment of our various mission demands.

Slide Presentation

When it comes to cockpit design considerations, we are at somewhat of a disadvantage. I come from a fragmented community. The best thing we do at the present time is agree not to agree. We have not become sophisticated enough to express our needs through a universally accepted agency, such as Airborne Law Enforcement Association. Our missions are so varied that the equipment we buy is not standardized. What is needed for rescue operations is not necessarily the best equipment for urban police patrol environment.

Our experimentation is limited to what an individual agency is willing to try, or can afford to buy. Research and development of a new item is unheard of. We are adapters. We adapt existing off-the-shelf items to our existing helicopters.

This is not to say that we should not be counted in design considerations. It is no secret that many commercial helicopter designs can find their roots in the dictates of military considerations. The LHX, for example, is being designed for the external defense of our country. We in public service are charged with the internal defense and security of our country in the form of crime suppression, traffic enforcement on our highways, fire fighting, rescue, medivac...all to provide a sage environment for YOU to live and work. Our mission is just as important. We need equipment that is just as sophisticated and, unfortunately, just as expensive as that provided to our men in arms.

Throughout our nation's history, there has been far more death and destruction on our streets and highways than the combined losses have been of both world wars and the two "police actions" in which our nation was involved.

There is no single piece of equipment that can uniformly effect the efficiency and effectiveness of public service agencies across this nation than a properly equipped helicopter.

Currently, our mission profile looks like this:

PRESENT MISSION PROFILE

- PRIMARY MISSION INVOLVES SPEED, FAST VISUAL ASSESSMENT AND COMMUNICATIONS
  - DAY – NIGHT VFR   1.5 MILES VISIBILITY
  - 24 HOURS A DAY AVAILABILITY – 10 HOURS FLIGHT TIME
  - 1.5 – 2 HOURS DURATION   MODERATE RAIN/35 KNOT WINDS
  - 500 – 700 FOOT AGL
  - 50 – 140 KNOTS
  - 1 – 50 MILES FROM BASE
  - CREW   PILOT/OBSERVER (CLERICAL RECORDER)

In the future, we anticipate our mission profile to look something like this:

FUTURE MISSION PROFILE

- REGIONAL CONCEPT
  - DAY – NIGHT VFR/IFR
  - 24 HOURS A DAY CONTINUOUS
  - 1.5 – 3 HOURS DURATION HEAVY RAIN/45 KNOT WINDS
  - 800 – 1200 FOOT AGL
  - 50 – 250 KNOTS
  - 1 – 250 MILES FROM BASE
  - CREW . . . . PILOT/OBSERVER/CREW SPECIALIST

In 1980, a workshop was held here at Ames on the "Helicopter Technology Benefits and Needs for a Public Service Helicopter." Out of this three day meeting came a shopping list of needs identified as necessary to our future successful operations. (Contract NAS2-10411)

TECHNOLOGY NEEDS

- NAVIGATION/GUIDANCES/ FLIGHT CONTROLS

1. AUTOMATIC FLIGHT CONTROL
2. COMBINED CONTROLS
3. STABILIZATION
4. ALL WEATHER CAPABILITY
5. LOW AIRSPEED MEASUREMENT
6. ELECTRONIC MAP DISPLAY
7. PRECISION LOCATION NAVIGATION

HUMAN FACTORS

1. IMPROVED SEATS
2. ENVIRONMENTAL CONTROL
3. NOISE AND VIBRATION
4. CONTROL STANDARDIZATION
5. DUAL CONTROLS
6. VISIBILITY
7. INTEGRATED FLIGHT INSTRUMENTS
8. PRESSURIZED
9. BIRD STRIKE PROTECTION

- MONITORING & DIAGNOSTIC SYSTEMS

1. TREND WARNING
2. COMPUTERIZED MONITORING SYSTEM
3. WARNING/CAUTION SYSTEM
4. COLOR CODED ANNUNCIATION
5. AURAL WARNING
6. HEAD-UP DISPLAY
7. PERFORMANCE LIMITATIONS

In addition to these, there are many opportunities for current technology transfer to the public service marketplace. For example, the MMS from the AHIP program would work wonders for us if it was mounted underneath the helicopter. Lazer and FLIR technology can easily be adapted to public service uses. Stabilized cameras and optics will become a must for our future work.

We have worked on a multi-mission vehicle of modular design that would fit our specific mission demands. We have all kinds of ideas, but no money.

I am not here today seeking funding. I am here to inform you of a little known, but fast growing, segment of the marketplace that needs to be considered in your design parameters. We wish we were in a position to dictate design, but, since that is not possible, we at least can inform you of our needs.

Thank you very much.

D7

N85 14813

SAR
MARITIME MISSIONS

By

David A. Young
Sikorsky Aircraft
Stratford, Connecticut

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US COAST GUARD SRR MISSIONS

- Search and Rescue
- Enforcement of Laws and Treaties
- Marine Environmental Patrol
- Light Utility Transport

All Weather Operations,
Ship or Shore Based

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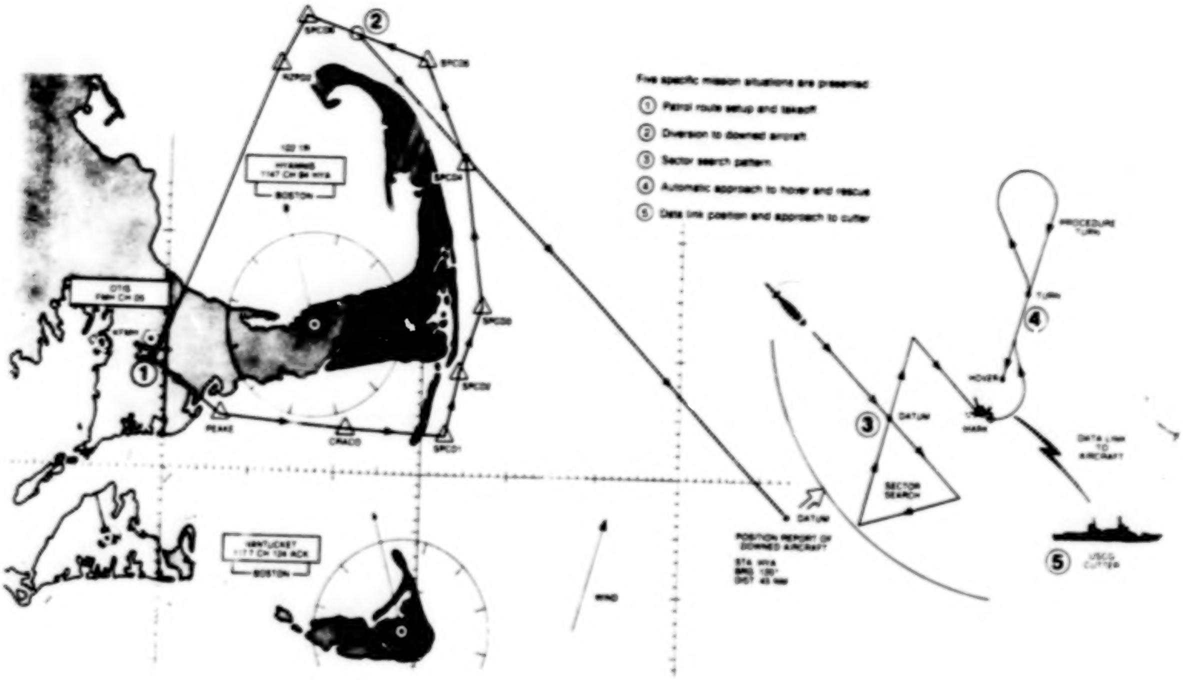
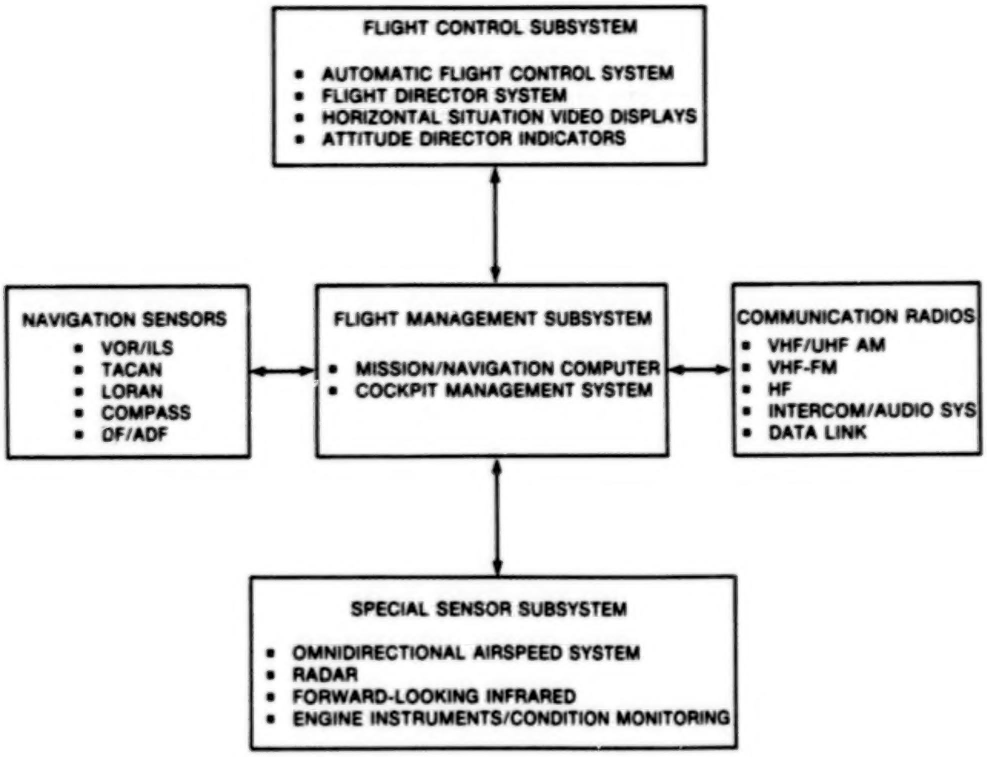
SRR MISSION SUMMARY


Five specific mission situations are presented:
① Patrol route setup and takeoff
② Diversion to downed aircraft
③ Sector search pattern
④ Automatic approach to hover and rescue
⑤ Data link position and approach to cutter
SPC06
SPC05
NZP03
SPC04
SPC03
SPC02
SPC01
PEAKE
GRACO
OTIS
HYANNIS
BOSTON
NANTUCKET
BOSTON
WIND
DATUM
POSITION REPORT OF DOWNED AIRCRAFT
SECTOR SEARCH
HOVER
MARK
TURN
PROCEDURE TURN
DATA LINK TO AIRCRAFT
USCG CUTTER

C-2

THE SRR INTEGRATED AVIONICS SYSTEM


FLIGHT CONTROL SUBSYSTEM
• AUTOMATIC FLIGHT CONTROL SYSTEM
• FLIGHT DIRECTOR SYSTEM
• HORIZONTAL SITUATION VIDEO DISPLAYS
• ATTITUDE DIRECTOR INDICATORS
NAVIGATION SENSORS
• VOR/ILS
• TACAN
• LORAN
• COMPASS
• DF/ADF
FLIGHT MANAGEMENT SUBSYSTEM
• MISSION/NAVIGATION COMPUTER
• COCKPIT MANAGEMENT SYSTEM
COMMUNICATION RADIOS
• VHF/UHF AM
• VHF-FM
• HF
• INTERCOM/AUDIO SYS
• DATA LINK
SPECIAL SENSOR SUBSYSTEM
• OMNIDIRECTIONAL AIRSPEED SYSTEM
• RADAR
• FORWARD-LOOKING INFRARED
• ENGINE INSTRUMENTS/CONDITION MONITORING

FLIGHT CONTROL SYSTEM FUNCTIONS

- Three Axis Stability/Command Augmentation
- Automatic Trim
- Automatic 4-Axis Coupled Path Control
- Helicopter Path Steering
- Flight Guidance and Situation Displays
- Fail-Passive Safety

FLIGHT MANAGEMENT SYSTEM FUNCTIONS

- Centralized Avionics Control (Comm, Nav, IFF, Data Link, Voice Scrambler, MCU)
- Automatic Position Fixing
- Automatic Nav Sensor Selection and Tuning
- Flight Planning (RNAV - Style)
- Automatic Search/Rescue Patterns
- Automatic Lateral and Vertical Guidance
- Fuel Management
- Engine Condition Monitoring

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CONVENTIONAL NAVIGATION FUNCTIONS

- Dual VOR/ILS/MB
- Tacan
- Dual Loran
- DF/ADF

SRR COCKPIT LAYOUT

COMMUNICATION FUNCTIONS

- Dual UHF/VHF/FM "Combo" Transceivers
- Maritime FM
- HF
- ATC Transponder
- Data Link
- Voice Scrambler
- Loud Hailer
- Intercom/Audio System

INTEGRATED AVIONICS SYSTEM FUNCTIONS

- Relieve Pilot of Routine Duties
- Precision Guidance - Search Patterns, Approach to Hover
- Automated Calculation Assistance — Fuel, Range, Time, Pattern Spacing
- Monitor Engine Conditions for Maintenance
- Improve Flight Safety and Consistency
- Organize Cockpit Functions Efficiently

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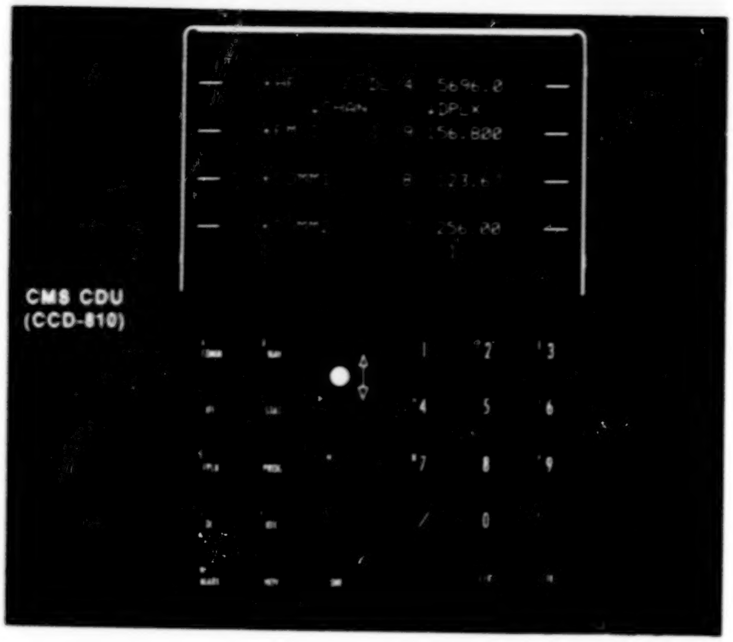
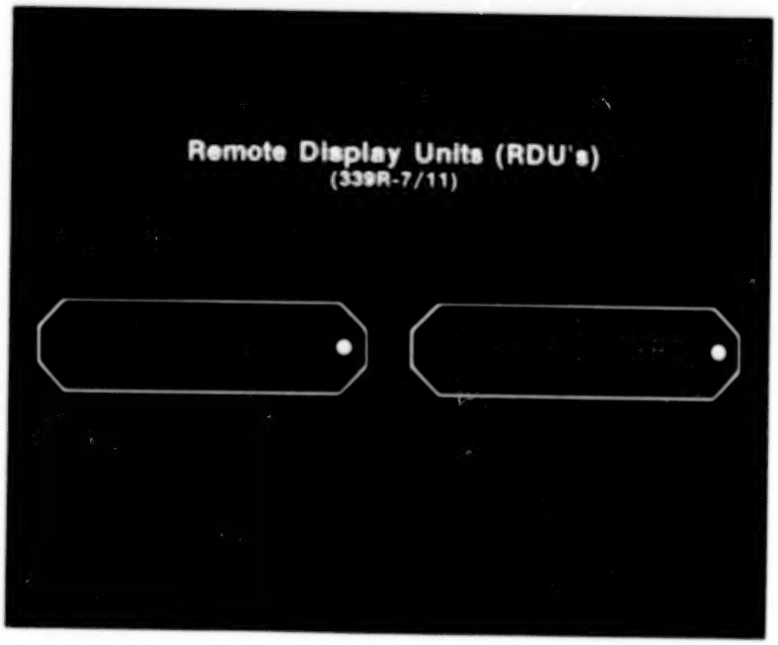


CMS CDU
(CCD-810)



Remote Display Units (RDU's)
(339R-7/11)

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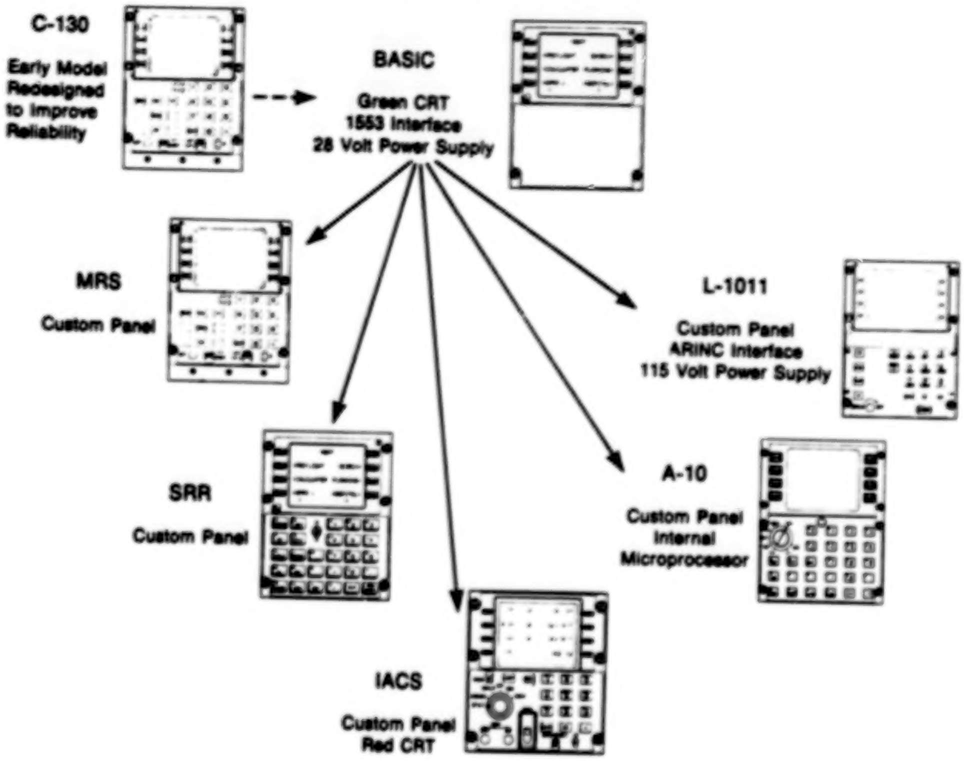
CDU VERSATILITY



C-130

Early Model
Redesigned
to Improve
Reliability

BASIC

Green CRT
1553 Interface
28 Volt Power Supply

MRS

Custom Panel

L-1011

Custom Panel
ARINC Interface
115 Volt Power Supply

SRR

Custom Panel

A-10

Custom Panel
Internal
Microprocessor

IACS

Custom Panel
Red CRT

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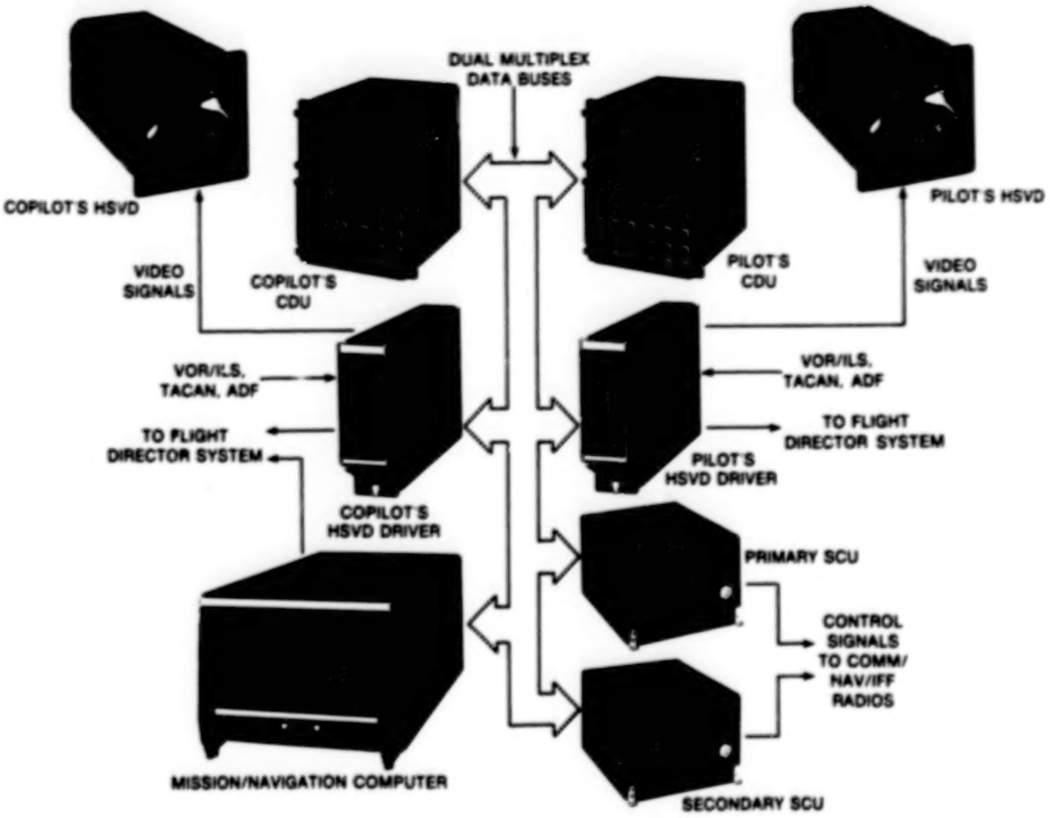
MULTIPLEX DATA BUS STRUCTURE


DUAL MULTIPLEX DATA BUSES
COPILOT'S HSVD
PILOT'S HSVD
VIDEO SIGNALS
COPILOT'S CDU
PILOT'S CDU
VIDEO SIGNALS
VOR/ILS, TACAN, ADF
VOR/ILS, TACAN, ADF
TO FLIGHT
TO FLIGHT DIRECTOR SYSTEM
DIRECTOR SYSTEM
PILOT'S HSVD DRIVER
COPILOT'S HSVD DRIVER
PRIMARY SCU
CONTROL SIGNALS TO COMM/ NAV/IFF RADIOS
MISSION/NAVIGATION COMPUTER
SECONDARY SCU

HOW IS THE HH-65A AVIONICS SYSTEM INTEGRATED?

- Multiplex Data Bus
- Distributed but Complementary Processing
- Multifunction Control/Display Units
- Multifunction Flight Situation Displays
- Integrated Operation —
  Minimum Required Pilot Actions

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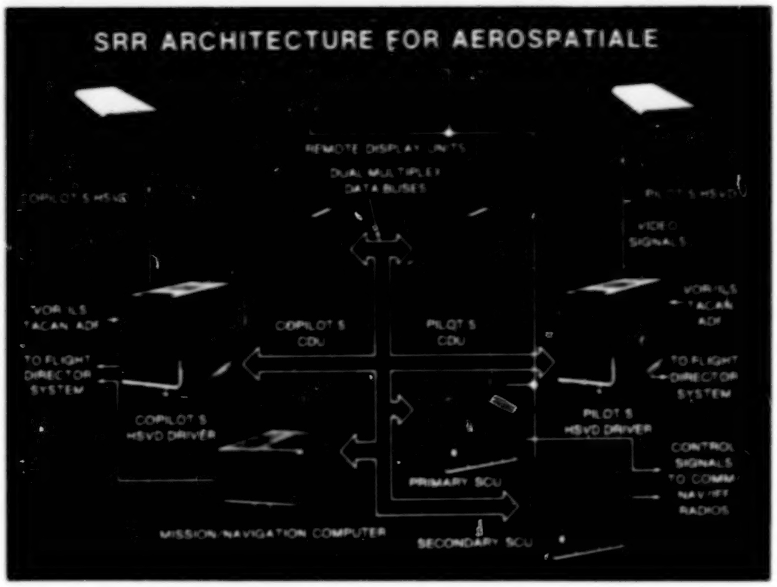
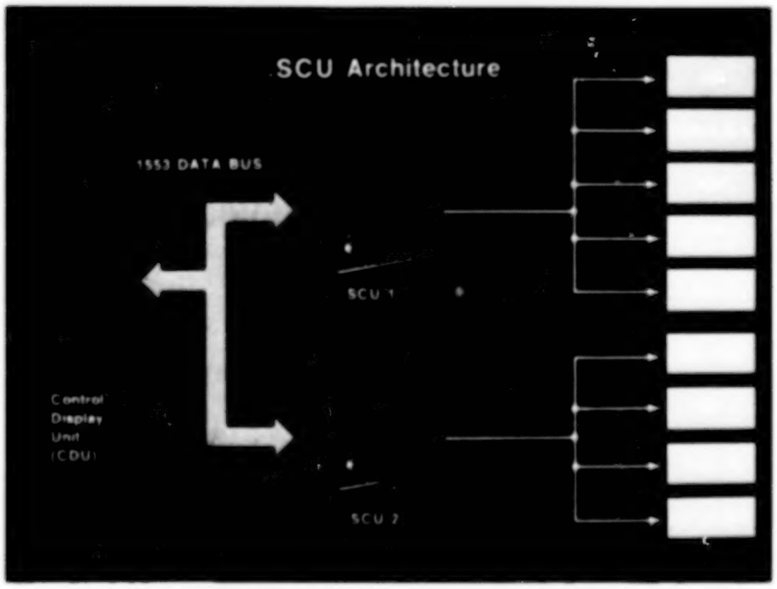


SRR ARCHITECTURE FOR AEROSPATIALE

REMOTE DISPLAY UNITS
DUAL MULTIPLEX DATA BUSES
COPILOT'S HSVD
PILOT'S HSVD
VIDEO SIGNALS
VOR/ILS TACAN ADF
COPILOT'S CDU
PILOT'S CDU
VOR/ILS TACAN ADF
TO FLIGHT DIRECTOR SYSTEM
TO FLIGHT DIRECTOR SYSTEM
COPILOT'S HSVD DRIVER
PILOT'S HSVD DRIVER
CONTROL SIGNALS TO COMM/NAV/IFF RADIOS
PRIMARY SCU
MISSION/NAVIGATION COMPUTER
SECONDARY SCU



SCU Architecture

1553 DATA BUS
SCU 1
SCU 2
Control Display Unit (CDU)

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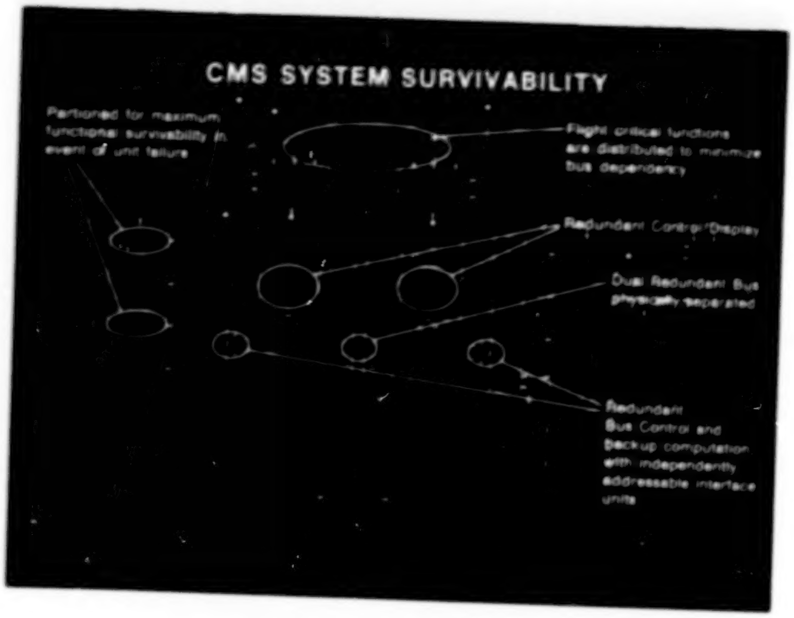

CMS SYSTEM SURVIVABILITY

Partioned for maximum functional survivability in event of unit failure

Flight critical functions are distributed to minimize bus dependency

Redundant Control/Display

Dual Redundant Bus physically seperated

Redundant Bus Control and backup computation with independently addressable interface units

N85
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UNCLAS

D3

N85 14814

SOME THOUGHTS ON THE IMPLEMENTATION OF PILOT NIGHT VISION DEVICES FOR HELICOPTERS

George E. Tucker
Research Pilot

NASA-Ames Research Center
Moffett Field, CA 94043

INTRODUCTION

An increasing number of government and civil agencies are finding that night vision enhancement devices greatly expand the range and quality of their services by extending their night operational capability far beyond the limits of the unaided eye. Envolving military tactical concepts for helicopter survivability and battlefield effectiveness necessitate nap-of-the earth (NOE) flying under both day and night conditions.

From a pilot workload standpoint, flying a helicopter NOE in day VFR conditions with minimum clearance between rotors and obstacles can be quite demanding. Doing the same job at night or in conditions of severly reduced forward visibility makes the job several times more difficult.

At present, there are two general categories of night visions devices in operation in helicopter aviation. These two are the Night Vision Goggles (NVG) and Forward Looking Infrared (FLIR) systems. The first uses light intensification technology while the second uses "thermal imaging" to provide the pilot with a view of the otherwise obscured world outside the cockpit. While markedly different in design, the two technologies overlap in terms of the capability provided. Each also has its own unique capabilities, strong points, and shortcomings.

Once these systems are in the inventory a soon-to-follow question is how far can they (and the pilots) be pushed operationally. The most reasonable answer is: No further than the pilot can comfortably stand. The pilot must always be able to do the expected and still have sufficient reserve capacity left over to handle the unexpected. If the equipment designer or operational commander takes that margin of capacity away, the safety of the willing pilot and that of a terribly expensive vehicle is placed in considerable jeopardy.

One wonders if we have refined these systems to a degree commensurate with the task that we are asking the pilot to perform?

In the following paragraphs I will confine the discussion of night vision systems to those which are either actively being used, or soon to be fielded, by U.S. Army aviation.

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NIGHT VISION GOGGLES

The system that has been around the longest (since the early 70's) is the AN/PVS-5 Night Vision Goggles with "second generation" light intensifier tubes (Figure 1).

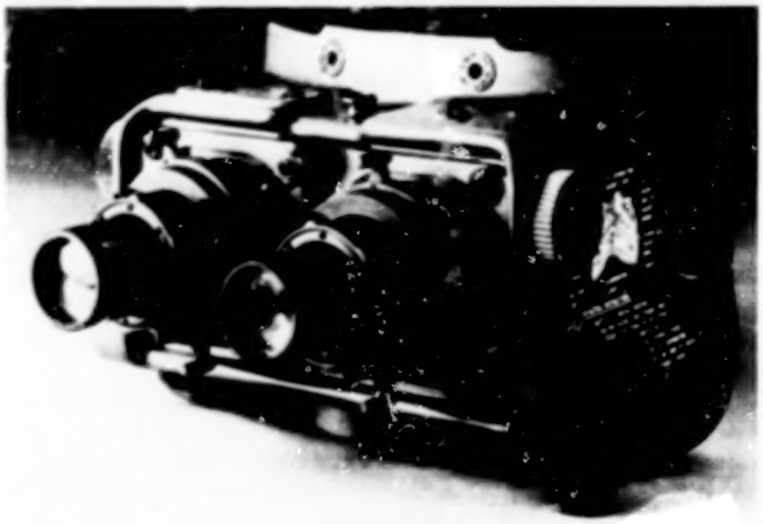

FIG. 1

This piece of gear was originally designed for ground vehicle drivers and subsequently borrowed by the aviation community to satisfy a perceived need. These systems have been loosely described as capable of turning night into day. More appropriately they turn SOME nights into something that resembles day, and then at a considerable price extracted from the user in the form of pilot workload and fatigue.

Some of the more significant system design capabilities and limitations are listed below:

1. 20/50 VISUAL ACUITY: This means the best the goggles can do is 2-1/2 times worse than the unaided eyeball. For the helicopter pilot it means that small or distant objects are not easily detected or well defined. Hovering over an open field, on NVG's, using only blades of grass or pebbles as hover references, is extremely difficult because the visual references are not clearly seen. Neither are slight variations in position or altitude. The result is a less stable hover resulting from a tendency to overcontrol the helicopter.

2. 40 DEGREE FIELD OF VIEW WITH ZERO PERIPHERAL VISION: Because the helicopter pilot relies so heavily on visual cues during hover and hovering landings and takeoffs, he will typically move his head 30 to 40 degrees to the side and down to perceive parallax and relative motion. However, with the AN/PVS-5 system, the mount for the intensifier tubes is an enclosed facemask design which fits snuggly against the pilot's face. This design feature and the added constraint of a 40 degree field of view in the optics requires the pilot to constantly shift his head 90 degrees to the side and downward to compensate for the lost peripheral vision.

On approach to a hover, failure to rotate the head will result in a failure to sense the rate of forward motion and a likely overshoot of the landing spot. Similar head movement is required in a hover to prevent the pendular motion of the aircraft that occurs when the pilot is slow to perceive the onset of airframe translation with respect to the ground. The aircraft will have developed significant translational velocity before the arresting control input is applied. The inexperienced pilot's control response is typically excessive resulting in a higher than desired translational rate in the opposite direction, and the onset of the pendular motion. Constant head movement is therefore required to quickly detect any shift in aircraft position.

3. MANUAL FOCUS AND LIMITED DEPTH OF FIELD: The limited depth of field of the NVG optics combined with the enclosed face mask poses some additional problems. In order to see both the outside world and the interior cockpit environment the pilot must either refocus for each change of objective or focus one tube for infinity and the other for the instrument panel. The first option is critically time and attention consuming. The latter is conducive not only to the rapid onset of visual fatigue and headaches but further reduces the pilot's visual field. The solution in dual cockpits has been for the pilot to focus outside and the copilot either to focus inside or hand-hold his goggles so that he can look below them at maps and the instruments.

4. POOR LOW LIGHT CAPABILITY: The effectiveness of the goggles is related to the level of ambient illumination. Whereas no moon is required for enroute flight at altitude, a minimum of 1/4 to 1/2 moon is required for low level operations. Starlight-only operation is not feasible unless supplementary artificial illumination is provided. While the goggles always present the pilot with a monochromatic green scene, low light levels rob the pilot of the subtle detail due to the decreased resolution and sharpness. For this reason, pilots in general seem to feel they need more light as they get closer to the ground. When the light level is lower than the pilot needs, he will tend to overcontrol, become tense, and fatigue more easily.

Available contrast in the area viewed also affects the pilot's visual threshold. Areas of high contrast are displayed with much greater clarity through the goggles. Consequently, hovering next to a tree line is much easier than over a wide expanse of short grass.

Since light level and contrast affect the pilot's visual threshold they also affect the useful range of the goggles. This characteristic in turn affects the airspeed and severity of flight maneuvers that a pilot can fly. Poorly illuminated conditions cause the pilot to fly more slowly, higher, and maneuver more mildly than he might otherwise.

Another unique feature of the goggles is that they can detect light sources from greater distances than the human eye can. If the goggles are subjected to a relatively bright source of light, the automatic brightness control will aadjust the gain of the tubes to hold the output brightness at a preset level. While the brightness of the image has been maintained, the overall scene definition is reduced until the bright source of light is removed from the field of view. If, on the other hand, the level of ambient light goes below the useable threshold of the goggles the pilot begins to see "sparklies" in the image, which is the goggle's way of telling the pilot that they are at maximum output.

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5. UNITY MAGNIFICATION AND POOR DEPTH PERCEPTION: The goggles are biased to produce an apparent magnification of one. The bias in itself produces alteration of size and distance perceptions. Landing areas appear smaller and farther away producing the tendency to overshoot approaches and terminate high. At close range the illusion diminishes sometimes leaving the pilot too fast for a safe landing. The natural tendency is to overcompensate by intentionally flying slower and lower on approaches which results in excessively long and shallow approaches.

6. FATIGUE: The anxiety of flying in such a demanding and unforgiving environment combined with the physical demands of the goggles themselves increases the onset rate of fatigue. There is no time to "let up" or rest until you remove yourself from the NOE environment. In addition to the eye strain that comes with viewing the goggles for long periods of time, the 30 ounces of cantilevered weight on the pilot's face rapidly fatigue the muscles of the back and neck.

ANVIS GOGGLES

Fortunately for night vision goggles users the follow-on ANVIS or Aviator Night Vision Imaging System (AN/AVS-6) (Figure 2) is soon to be fielded, at least in limited quantities. These lightweight, high-performance goggles incorporate "third generation" light intensification tubes and some excellent corrective engineering. I will briefly compare this newest goggle configuration in the same general categories as the AN/PVS-5's.

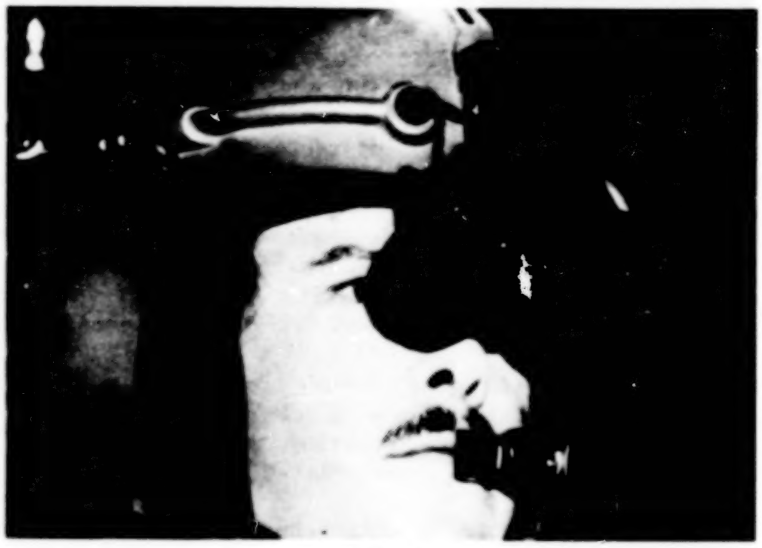

FIG. 2

1. 20/40 VISUAL ACUITY: Slightly better visual acuity by optical design.

2. 40 DEGREE FIELD OF VIEW BUT WITH EXCELLENT "SEE AROUND" CAPABILITY: Although the field of view has been held constant to maintain satisfactory resolution, most of the material around the tubes themselves has been stripped away. Viewing the night scene through the goggles has been likened to looking

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at a bright spot in an otherwise dark surround. The pilot now has the option of using any peripheral cues that the ambient illumination will allow, and with the proper blue-green filtered cockpit lighting, he can easily read the cockpit instruments as well as his map.

3. FOCUS: With the excellent peripheral access afforded the pilot, there is no longer a need to refocus or remove the goggles to view items in the cockpit. The pilot now needs only to look beneath or around the tubes.

4. GREATLY INCREASED LOW LIGHT CAPABILITY: Incorporation of third generation light intensifier tubes in the ANVIS goggles results in far greater sensitivity in the red and near-infrared regions of the electromagnetic spectrum. Whereas the ANVIS goggles and the AN/PVS-5"s have roughly the same capability under conditions of a quarter moon or greater, the ANVIS goggles are said to be effective down to conditions of overcast starlight.

5. STILL UNITY MAGNIFICATION: Although the magnification is still unity, the increased contrast and resolution provide additional cueing to reduce the illusion of minification of the scene.

6. GREATLY REDUCED FATIGUE LEVEL: The reduced system weight and improved center of gravity greatly reduce the physical discomfort while the peripheral access and increased visual acuity reduces the pilot workload and anxiety associated with the night NOE environment.

All in all, the ANVIS goggles are a remarkable stride forward in the night vision world. They are a compliment to those individuals in the "system" who ask the probing questions, listen to the "voices of experience", and see that the way we have been doing things is not necessarily good enough!

PILOT NIGHT VISION SYSTEM

The AH-64 APACHE attack helicopter will be fielded with the Pilot Night Vision System. Rather than light intensification this system uses thermal imaging to provide the pilot with a visual image of the target viewed by the infrared sensor. Figure 3

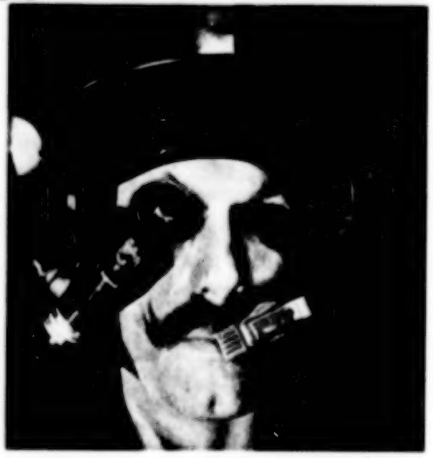

FIG. 3

illustrates the working-end of the system as far as the pilot is concerned. The combiner glass that sits in front of the pilot's right eye presents an 875-line, cathode-ray-tube (CRT) image which is .75 inch on the diagonal. The field of view is 30 by 40 degrees. The turreted FLIR sensor is slaved to the pilot's helmet motion allowing the pilot to move his 30 by 40 degree field-of-view through a "field-of-regard" of +/- 120 degrees in azimuth, 35 degrees in elevation, and 65 degrees in depression with respect to longitudinal centerline through the sensor. Superimposed upon the FLIR imagery is a full seethrough, HUD-like symbology which provides the information that is required to perform most flight tasks.

The following video tape will illustrate the imagery and symbology as used by the author during a familiarization/training flight in one of the AH-1S "surrogate trainers" for the AH-64. Keep in mind that what you are seeing is an image constructed from differences in the thermal emissivity of objects in the target scenes and not an intensification of a visible light pattern.

(VIDEO TAPE PRESENTATION)

Now let us look at this system in some of the same areas considered in the NVG discussion.

1. VISUAL ACUITY: No figures available.

2. FIELD OF VIEW: The 30 x 40 degree field-of-view provides a rectangular picture that seems to fill the full visual field of the eye, giving the pilot the feeling of "being in the picture". The frequency response of the sensor turret is such that there is little sensible lost motion between pilot head movement and the writing of the CRT image. However, the fact that the turret is on the nose of the aircraft, well ahead of the pilot, produces some significant parallax problems when viewing obstacles which are close aboard and passing aft along the side of the aircraft. An object which passes out of the field-of-regard of the turret may not yet be abeam the pilot and certainly not abeam of the tail rotor.

3. PERIPHERAL VISION: The location of the combiner glass on the pilot's right cheek effectively eliminates peripheral vision on the right side. However, the left eye is free to receive whatever images it will while slaved to the right eye. Herein lies a significant source of an effect referred to as "binocular rivalry". The pilot must be able to discipline himself to make the right eye the "master" eye when the PNVS image is of interest and the left eye master when cockpit instrumentation or maps are of primary interest.

4. LOW AMBIENT LIGHT LEVEL: In a FLIR system the light level is meaningless. The sensor responds to the differential infrared emissivity of objects in the target scene and contrasts them as different shades of phosphorescent green in the display. The image can be presented as either "white" or "black hot", depending on which is most situationally agreeable to the viewer. Whereas low ambient light level is the Achilles' heel of the NVG, the emissivity crossover point presents a similar problem for the FLIR. This is the point at which two objects which are changing temperature temporarily have the same emissivity value, rendering them indistinguishable from each other in the display. Scenes which consist of objects of widely varying temperature and emissivity offer more contrast than areas which are more uniform. It should also be mentioned that FLIR systems do suffer some signal attenuation in the presence of high atmospheric moisture levels.

A significant advantage in the use of thermal imaging is the potential for viewing day scenes where obscuring phenomena severely reduce slant range visibility, e.g. blowing dust or smog. The FLIR is capable of seeing through such daylight obscurations while the NVG's are limited to viewing that which normal day optics can detect and then only in relative darkness.

5. UNITY MAGNIFICATION AND DEPTH PERCEPTION: This system incorporates a collimated image focused at infinity with unity magnification. As a result the target scenes invariably appear much further away than they actually are. On final approach to a landing zone one can appear to be somewhere in midapproach when in fact he is on short final. Experience and proficiency are required to deal with this illusion effectively.

6. FATIGUE: The helmet and helmet mounted display for this system are relatively heavy and slightly unbalanced laterally. To ensure no lost rotational motion between the pilot's head and the helmet (to which the sensor is slaved), a snug fit is essential. The resultant of these factors is a helmet liner given to producing "hot spots" on the pilots head. Add to this constant binocular rivalry combined with the wide-eyed, rapt attention that the pilot must devote to the display content, and the result is exceptionally high pilot workload and the rapid onset of fatigue.

IN CONCLUSION

The above-described systems all "work" and have been used with varying degrees of success in areas from extended research and development up through full field use. They all are high to very high pilot workload systems which demand the pilot's total concentration in the NOE environment. Not every pilot is going to be operationally capable, or safe, with all of these systems, or, perhaps any, under the most demanding and stressful of NOE situations. Those pilots that are good with them will have varying degrees of day-to-day success with the systems depending on the level of enthusiasm, proficiency, and situational awareness that they bring to the task. Ultimately, the individual pilot determines the upper limit of system operational capability by determining that point at which his individual capabilities don't match the situational demands.

Before concluding I would like to reiterate some things which may be patently obviously to you all, but I think, well worth emphasizing:

1. Increased mission complexity is stimulating rapid technological evolution while the human pilot evolves hardly at all. We seem to be able to think up all matter of new machinery to "help" the pilot without giving proper due to the real physical and mental workload that is required to integrate it into an ever increasingly complex cockpit. Not that the average pilot is a mental defective, but the old military acronym of "KISS — Keep it simple, stupid" may promote more truly useable system designs.

2. The mission capacity of the human behind the weapon system changes considerably from day to day due to complex life stresses alone. The fact that a new system works well in the lab or in simulation or on a sterile test range does not necessarily mean that it will do as well when flown by the average line pilot who is carrying a big load of social, family, legal, and financial stresses around in his kit, all competing with the system for his random attention.

3. The "I can do it" attitude is strong in the basic human pilot in both the test and operational communities. Beware that the subtle pressures of being considered the "best" and therefore the first to evaluate a new system doesn't bias out the "I can't quite seem to do it" pilot comment for some corner of the envelope. The oft jokingly repeated phrase from the carrier aviation community that "it's better to die than look bad (around the boat)" may have a grain of applicability in it somewhere.

RECOMMENDATIONS TO ASSESS

I would also like to leave you with a few personal concerns that I will translate into recommendations for the researcher/designer/builder/commander:

1. Be darned realistic about the bounds of human pilot capabilities. Don't confuse his number/sensory crunching ability with that of the computer that you've put on board to help him out.

2. Design with 10% reserve pilot capacity, not -10%. Make your helpful systems transparent rather than obstacles to work around.

3. Work harder to find accurate measures of total pilot workload.

4. Don't put the pilot in the position where he sees himself as the weak link in the glorious system.

5. After you field a razzle-dazzle system, be extremely alert to operator problems. Investigate developmental incidents, not operational accidents.

6. Establish and maintain an unrestricted flow of information between the lab and the field.

7. Provide more than just adequate training to your troops, then be uncompromising in your adherence to currency and proficiency standards. Never turn your back and assume that technology is taking care of you.

I thank you all for your kind interest and attention.

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LHX/ARTI MISSIONS

Mr. E. J. Hartzell

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SESSION 3

ADVANCED INTEGRATED DIGITAL AVIONICS TECHNOLOGY

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HH-65A DOUPHIN DIGITAL INTEGRATED AVIONICS

Mr. R. B. Huntoon

Collins Government Avionics Division
Cedar Rapids, Iowa

Communication, navigation, flight control, and search sensor management are classical avionics functions which constitute every Search and Rescue (SAR) operation. In theory, however, communication, navigation, and flight control are merely handmaids to the search effort - the sole reason for the mission. Routine cockpit duties often monopolize crew attention during SAR operations and thus impair crew effectiveness, the United States Coast Guard presented industry with a challange: Build an avionics system that automates the routine tasks of communication, navigation, mission management and flight control, and therefore, frees the crew to focus on the mission tasks which only they can perform - the visual search and FLIR/RADAR Interpretation[1].

On 14 June 1979, the USCG awarded Aerospatiale Helicopter Corporation (AHC) a contract for a Short Range Recovery (SRR) helicopter, the HH-65A. Teamed with AHC, Collins Government Avionics Division of Rockwell International designed the avionics system for the SRR helicopter.

INTEGRATED COCKPIT DESIGN

The Rockwell solution to the Coast Guard design mandate exceeds mere automation. From the pilot's viewpoint, the HH-65A "Dolphin" cockpit achieves three additional goals: (1) integrated systems operation with consistent, simplified cockpit procedures, (2) mission-task-related cockpit displays and controls, and (3) reduced instrument scan effort with excellent outside visibility.

To achieve these goals, Collins Government Avionics Division has implemented the HH-65A avionics to rely heavily upon "system integration." Historically, the SAR avionics systems of communication, navigation, search sensors, and flight control have existed independently. On the SRR helicopter, the flight management system (FMS) has been introduced. It coordinates or integrates these classical SAR avionics functions. In the HH-65A cockpit, the pilot interacts with the FMS rather than the individual subsystems. He uses simple, straightforward procedures to address distinct mission tasks and the flight management system, in turn, orchestrates integrated system response.

Features of the FMS are (1) distributed but complementary processing, (2) multiplex digital data bus technology, and (3) multifunction CRT controls and displays.

Distributed but complementary processing is an important integration concept used in the HH-65A. It's architecture does not hinge on one centralized computer for processing all navigation signals, displays, control inputs, etc. Instead, distributed processors perform specialized functions. The system coupler unit (SCU) manages communications between the avionics and controls radio tuning. The control display unit (CDU) provides pilot access to all flight management operations. The horizontal situation video display (HSVD) driver unit generates the navigation displays, and the mission computer (MCU) acts as both navigator and flight engineer. Without pilot action, the MCU calculates a "best estimate" of present position and velocity, automatically tunes the navigation sensors, enables flight planning, RNAV-style (including the generation of special USCG patterns), monitors fuel consumption, and records the engine and transmission condition (Figure 1).

These specialized processors perform distinctive tasks; yet, they cooperate as a single integrated system to accomplish mission objectives. A high-speed multiplex digital data bus enables uninterrupted communication between the avionics. Using discrete addresses, any two boxes can communicate with each other on the bus. To fly to a point, for example, the pilot indicates his intent on the CDU, which in turn communicates that intent to the mission computer. The MCU computes and displays the aircraft's navigational situation on the HSVD and CDU, then sends roll commands through the automatic flight control system.

Although centralized versus distributed processing does not necessarily alter cockpit operation, system survivability argures for distributed processing. A mission computer failure, for instance, impacts only RNAV capability; automatic navigation via TACAN, VOR, or localizer is not impacted. LORAN, controlled through the system coupler unit, also remains valid; and since the HSVD display drivers process all VOR and TACAN signals plus generate the navigation displays, the crew retains display guidance.

Another important integration tool is using one device to do the work of many. Four multifunctional CRT devices, dual control display units (CDU's), and dual horizontal situation video displays (HSVD's), inhabit the HH-65A cockpit (Figure 2).

The CDU is a single-point control for all flight management operations. By incorporating "function keys", the CDU controls numerous mission tasks: Pushing the COMM or NAV button dedicates the CDU to COMM or NAV radio tuning. Selecting FPLN dedicates the CDU to flight planning. Likewise, pushing the PROG or STAT keys transforms the CDU into flight progress or status reporting device. Having assigned the control display unit to a particular function, the crew uses the line select keys adjacent software labels to (1) tune individual radios, (2) set transponder codes and modes, (3) insert waypoints, plus a host of other functions (Figure 3).

Because the CDU centralizes all operational inputs, it simplifies pilot procedures. He communicates, navigates, flight plans, etc., without having to manage dedicated controls scattered throughout the cockpit.

Furthermore, the pilot uses consistent, uniform procedures to input information to the system. For instance, to insert a regularly flown patrol route as a flight plan, the pilot types the route identifier on the CDU scratch pad. Pushing the line key adjacent the destination label automatically inserts in sequence the waypoints which constitue that route (Figure 4). Whether the pilot tunes a radio, changes the transponder code, or enters a waypoint, he used the same procedure: scratch pad entry, line key select.

Nor is the pilot required to memorize manifold procedures, because the CDU display design leads him through the various mission operations. To flight plan a rendezvous, for example, the pilot pushes the INDEX key and a menu of functions appears (Figure 5). The arrow beside the rendezvous label indicates to push the adjacent key. Doing so calls up the rendezvous parameters, but the pilot does not have to remember which entries to make. Brackets (part of standard CDU symbology) cue him that he must enter the last known position and velocity of the vessel being intercepted. Likewise, the absence of brackets remind him that the system will automatically compute and display the time to the rendezvous as well as the bearing and distance to the target being intercepted.

Not only are the CDU displays easily interpreted, but its pages are organized logically from a pilot's perspective. COMM radio tuning and control depict this design principle: Mention COMM radio control and a pilot most frequently thinks of tuning frequencies. As a result, pushing the CDU COMM key calls up the COMM display, which allows tuning of all on-board communication radios. A pilot less frequently considers mode control for individual radios. Consequently, the COMM control pages are accessed through first level COMM display. Via these displays, the pilot selects transmit/receive modes, initiates simplex or duplex operation, sets squelch levels, etc. A pilot least frequently changes COMM preset frequencies; hence, the COMM presets are one more level removed, being accessed through the individual control pages.

Centralized control, uniform pilot procedures, CDU display design, and functional priority of CDU pages simplify pilot operation in the HH-65A.

As the CDU is a central point of avionics control, so the horizontal situation video display (HSVD) is a cental point for flight situation displays. The HSVD supplants several dedicated instruments: the conventional HSI, projected map, RADAR and FLIR displays, as well as a hover indicator (Figure 6).

Merely replacing conventional instruments is not, however, the purpose of the HSVD. Rather, it organizes data into "task-related" modes which not only present the pilot information needed for specific mission phases but also eliminates extraneous information. Consider the low altitude hover over water at night. Because the pilot generally faces a centrally positioned HSI which provides virtually no hover information, he scans several other instruments to interpret his hover situation. The HSVD's hover mode integrated all hover data into one central display: omnidirectional airspeed, longitudinal/lateral drift, radar altitude, computed wind, plus target position.

Remaining HSVD modes, likewise, satisfy other flight phase requirements: The HSI mode is primarily an approach display. The MAP mode serves en route navigation, where the flight plan ahead may be viewed. The RADAR and FLIR modes display the video images from these sources for searching. The RADAR MAP mode relates radar returns (weather/ground) to the flight plan. And the DATA mode, a north-up chart presentation, facilitates impromptu flight planning. These modes are selected for display on the HSVD panel (Figure 7).

Besides suiting information to flight phases, task-related displays denote complementary formatting. For example, because a pilot navigating cross-country uses wind information to plan the flight, the MAP mode incorporates a digital wind readout. By contrast, the pilot in a hover does not need wind information for flight planning; he needs to visualize wind velocity relative to the helicopter. Consequently, the hover mode incorporates a modified Beaufort wind arrow, which instantly pictures the changing wind velocity. Each pilot needs computed wind information but in a complementary format - dictated by the flight situation.

TYPICAL SAR OPERATION

Thus far, technical features of the HH-65A avionics system have been described. At this juncture, one might ask, "How does the integrated avionics system aid the pilot in the context of the SAR environment?" The following scenario intends to demonstrate integrated system operation, specifically, as it impacts cockpit procedures and workload in the SRR helicopter. Assume that a pilot were flying a routine patrol when the rescue coordinator calls and instructs him to proceed directly to the site of a ditched aircraft, initiate a search, and rescue reported survivors.

To navigate to the downed aircraft, the pilot types in the LAT/LONG position on his CDU (the mission computer also recognizes LORAN TD's, place-bearing-distance, or identifiers) and selects DIRECT TO. The mission computer creates a direct course to the point (Figure 8). It also continuously plots present position using dual LORAN, dual VOR, TACAN, dual compass systems, and precision omnidirectional airspeed sensor inputs; manages the navigation sensors (i.e., automatically selects navigation stations and tunes the LORAN, VOR and TACAN receivers); and flies the aircraft to the waypoint through the flight director. The HSVD MAP mode simultaneously displays the flight plan (Figure 9). This mode combines a tactical map presentation of flight plan waypoints and an abbreviated HSI, which the pilot uses with the progress and flight plan displays of the CDU to monitor en route progress.

Meanwhile, the mission computer has already assessed the fuel situation. Accounting for wind, the MCU calculates the fuel required to fly to the search point, proceed to the destination, and leave a 30-minute reserve. If on-board fuel is insufficient, the system warns the crew by announcing FUEL ALERT on the CDU. If sufficient fuel exists, the STATUS display translates the fuel reserve (i.e., fuel in excess of what's needed to fly to the destination) into hours and minutes of flight time, labeled BINGO. MCU fuel management gives the pilot instant visibility of his fuel status, and thus, how long he can search.

While the mission computer monitors fuel consumption, the data link system reports en route progress to the search coordinator, relieving the pilot of routine position reporting. He merely designates the communication radio and transmission interval on the CDU DATA LINK display. At the specified time, the integrated system automatically down-links information regarding aircraft position, status, and flight progress.

Eliminating routine flight management tasks frees the pilot to concentrate on system performance and flight progress. Pushing the PROG key on the CDU calls up the computed present position (LAT/LONG) and ground speed. Pushing the line key adjacent any flight plan waypoint provides instant access to waypoint data for that geographical point - time, distance, and course to the waypoint via the flight plan or via direct.

As the aircraft nears the search area, the pilot plans his search. He selects one of three available patterns (sector, ladder, or expanding square) and then defines the pattern parameters. For example, if he selects a sector search, the computer asks what track spacing is desired (Figure 10). (Note: The pilot may request search advisories by entering the sea state, visibility, cloud cover, and altitude; the MCU will compute the optimum track spacing.) Selecting "INSERT--" displays the flight plan, where inserting the pattern required only pushing a line key at the desired datum point. The misson computer automatically plots the pattern waypoints and displays them on the HSVD.

Upon reaching the target area, the aircraft automatically initiates the search while the crew concentrates on the search RADAR, FLIR (forward-looking infrared), and DF radio homing, or they scan the whitecaps below.

When the target is spotted, the integrated system, with minimal crew effort, abandons the search and expedites the rescue operation. Overflying the target location, the pilot pushed two buttons: MARK - to mark the target's location, and HOVER - to call up the approach-to-hover pattern. He inserts the approach-to-hover pattern into the flight plan and selects APPR on the flight director panel - triggering a chain of operational events. The system turns the aircraft down-wind to ensure a final approach into the wind, directs a minimun time procedure turn, and computes a five-degree descent to the hover transition point. Using the FD speed beep, the pilot may vary the approach speed. At 100 feet radar altitude, the FD APPR mode drops; T-HOV mode captures and slows the helicopter to zero ground speed at 50 feet RA - just short of the target (Figure 11). During the transition to hover, the HSVD automatically displays the HOVER mode. The computed wind, HOVER velocity commands, omnidirectional airspeed vector, and the marked target position enable the pilot to monitor the approach-to-hover maneuver as well as modify the hover conditions. If the pilot beeps either radar altitude or longitudinal/lateral airspeed, the indicators instantly verify his input (Figure 12).

While the survivors are hoisted to safety, the pilot decides his next course of action. Should a victim require immediate medical attention, he may choose to fly to a medical center rather than home base. With the push of the DATA mode button, the HSVD displays surrounding hospital locations in a north-up, chart presentation (Figure 13). To examine direct distance, time or course to any viable alternate, the pilot simply calls up waypoint data for the respective hospital through his CDU. If desired, the MCU will also compute the maximum range on that course. Once again, minimal pilot action activates integrated system response to enhance crew effectiveness.

The technological tools of digital data bus communication, distributed but complementary processing, and multifunction CRT controls and displays have effected integrated cockpit operation in the HH-65A. Although this system has been implemented for a SAR application, these techniques and this approach to operational cockpit integration will adapt to any helicopter mission. A system coupler unit and CDU which currently control radios could as easily control weapons systems. A mission computer and HSVD might as easily display terminal area approach procedures or tactical combat command and control data. Meanwhile, the HH-65A with it's integrated cockpit operation will benefit Coast Guard line pilots who undertake SAR despite adverse conditions.

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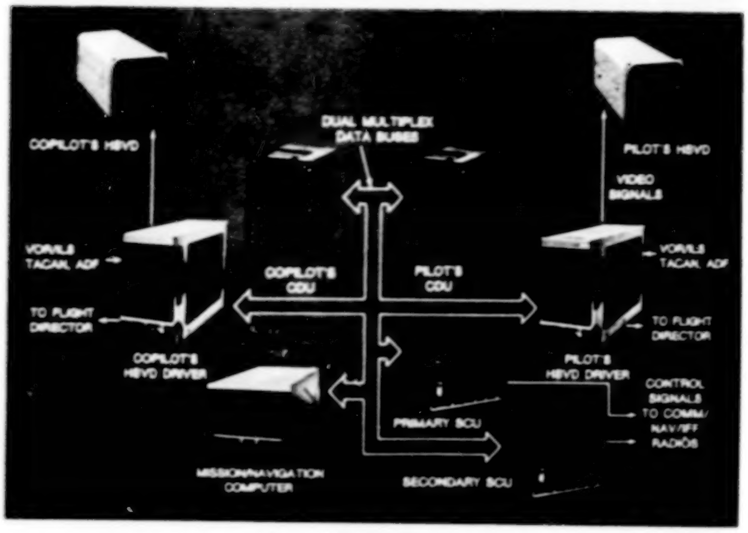
COPILOT'S HSVD
DUAL MULTIPLEX DATA BUSES
PILOT'S HSVD
VIDEO SIGNALS
VOR/ILS TACAN, ADF
COPILOT'S CDU
PILOT'S CDU
VOR/ILS TACAN, ADF
TO FLIGHT DIRECTOR
TO FLIGHT DIRECTOR
COPILOT'S HSVD DRIVER
PILOT'S HSVD DRIVER
CONTROL SIGNALS TO COMM/ NAV/IFF RADIOS
PRIMARY SCU
MISSION/NAVIGATION COMPUTER
SECONDARY SCU

FIG. 1

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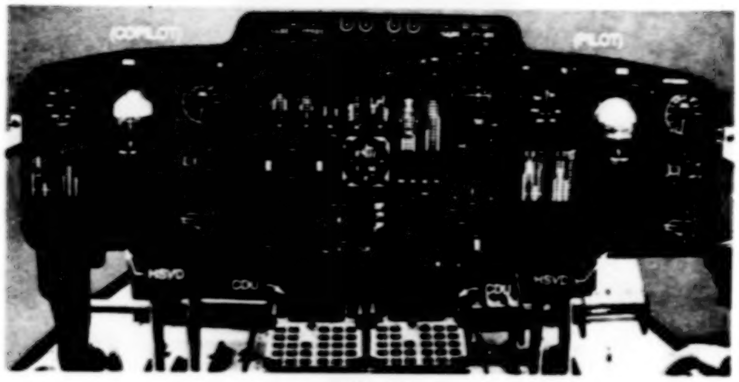
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FIG. 2

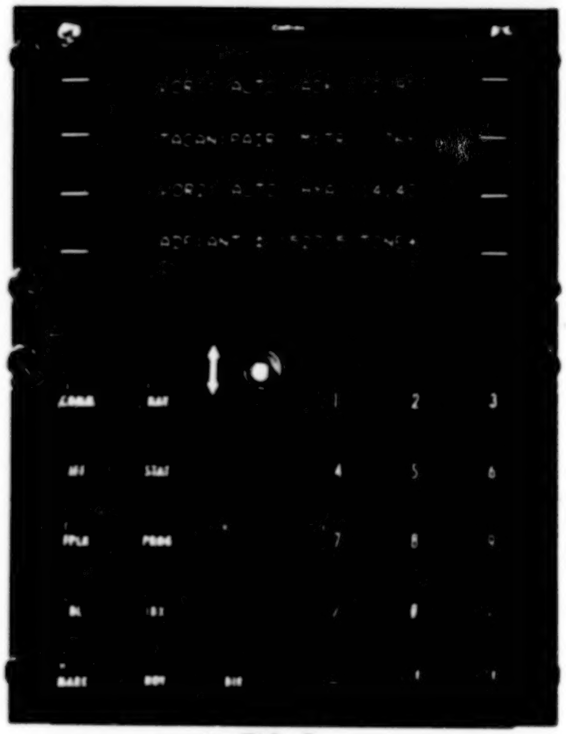
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FIG. 3

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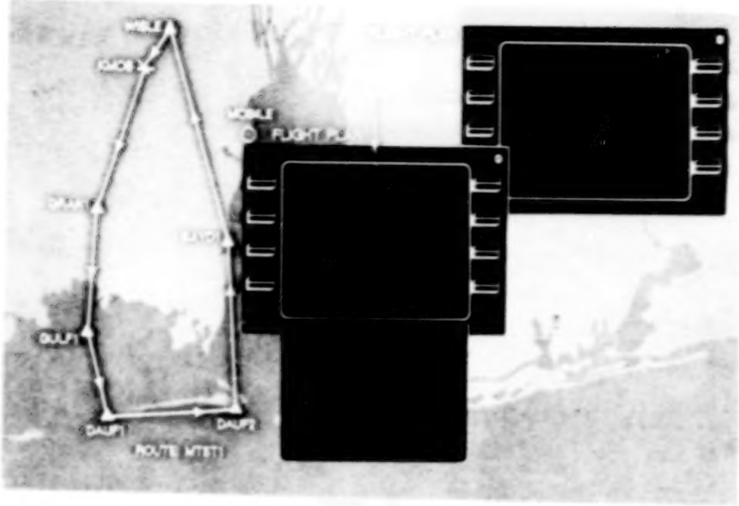
MOBILE
FLIGHT PL
GULF1
DALP1
DALP2
ROUTE MTST1

FIG. 4

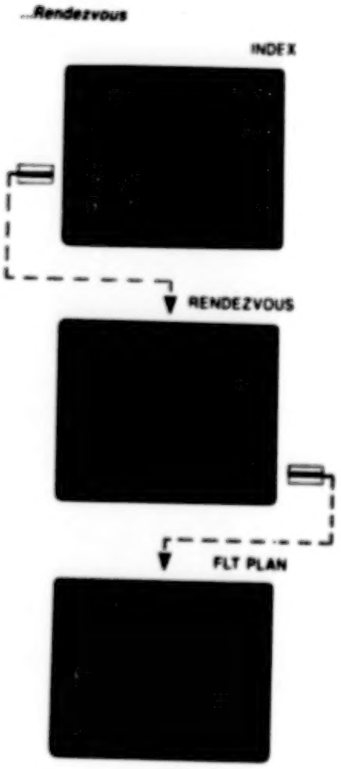
...Rendezvous
INDEX
RENDEZVOUS
FLT PLAN

FIG. 5

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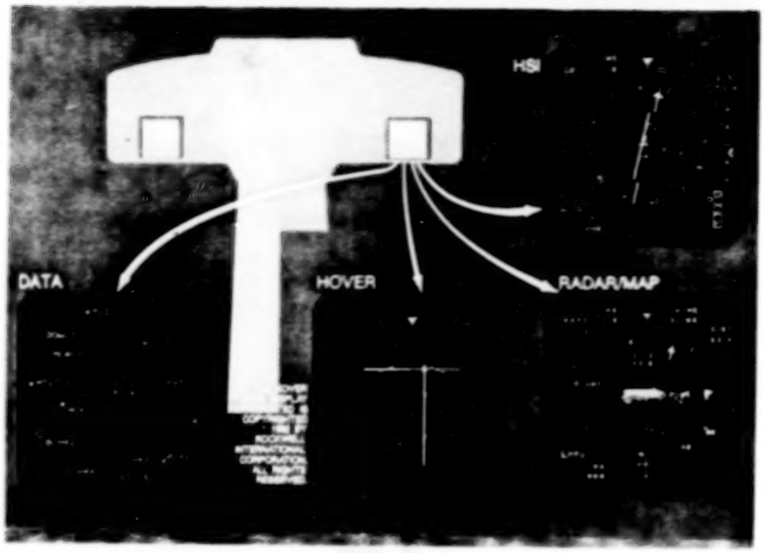
HSI
DATA
HOVER
RADAR/MAP

FIG. 6

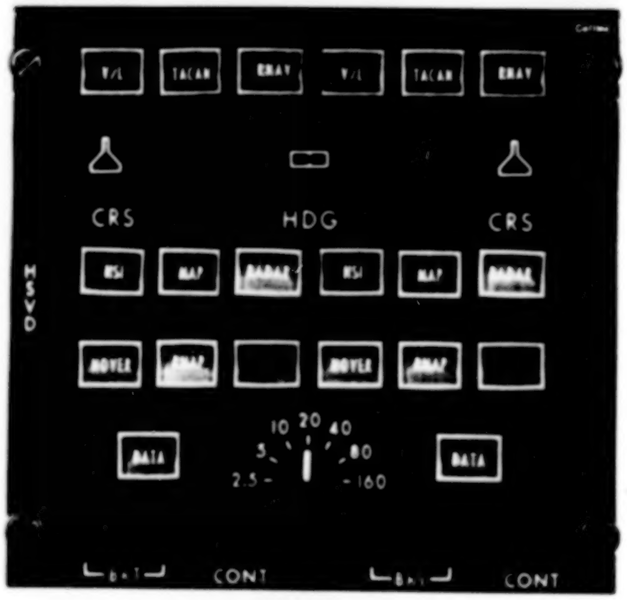
V/L
TACAN
RNAV
V/L
TACAN
RNAV
CRS
HDG
CRS
HSVD
HSI
MAP
RADAR
HSI
MAP
RADAR
HOVER
HOVER
DATA
10
20
40
5
80
2.5
160
DATA
BRT
CONT
BRT
CONT

FIG. 7

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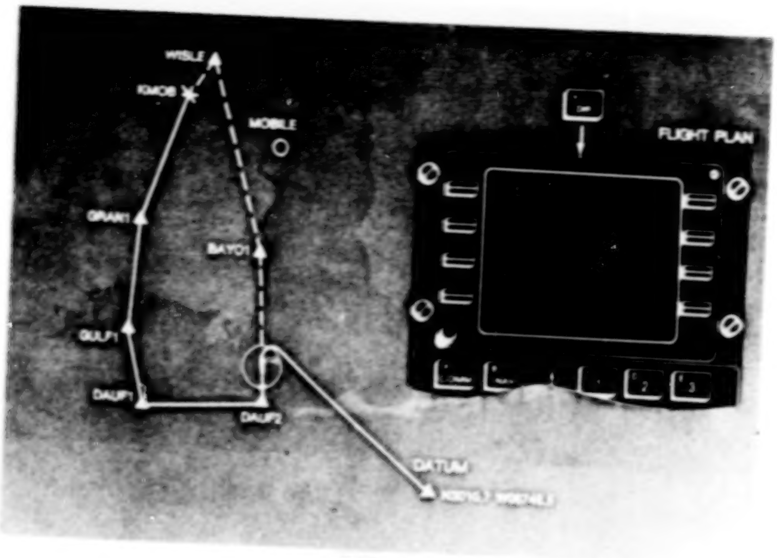
WISLF
KMOB
MOBILE
FLIGHT PLAN
GRAN1
BAYO1
GULF1
DAUF1
DAUF2
DATUM
N3010.7 W08746.5
2
3

FIG. 8

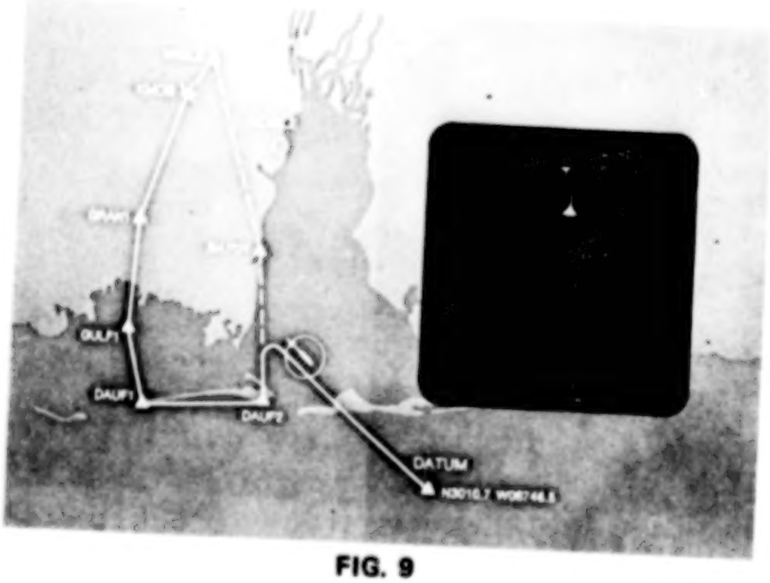
KMOB
GRAN1
BAYO1
GULF1
DAUF1
DAUF2
DATUM
N3010.7 W08746.5

FIG. 9

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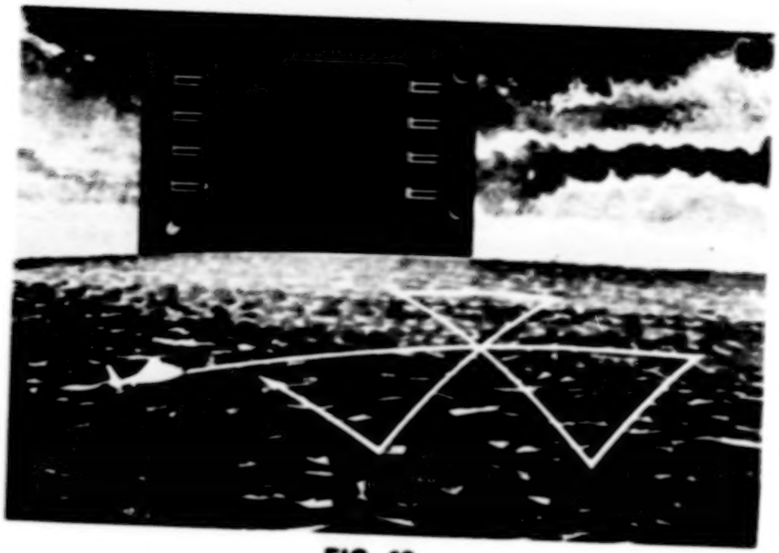

FIG. 10

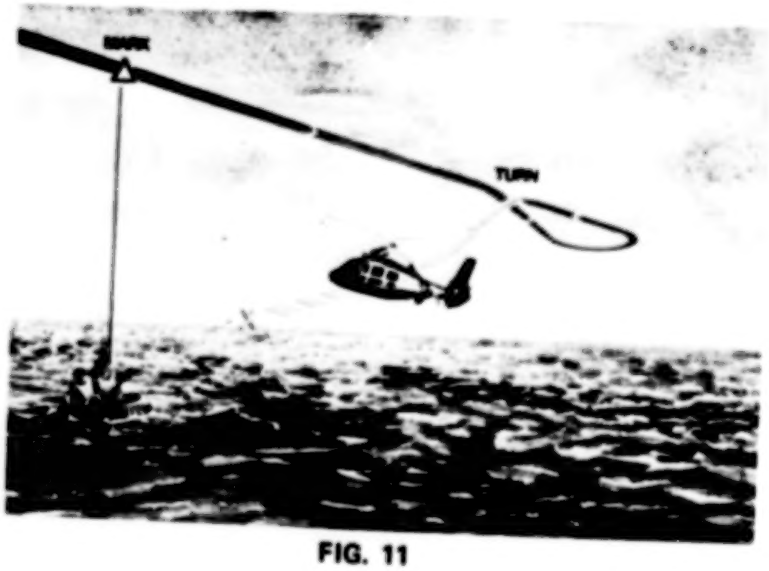

FIG. 11

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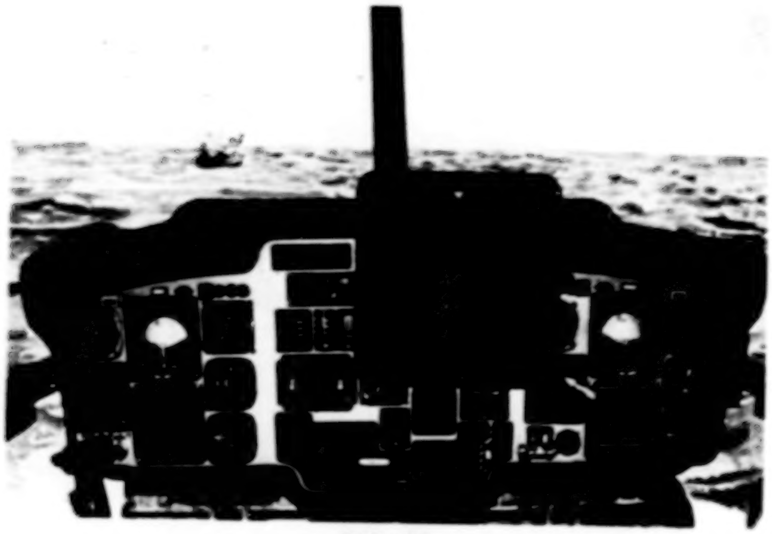

FIG. 12

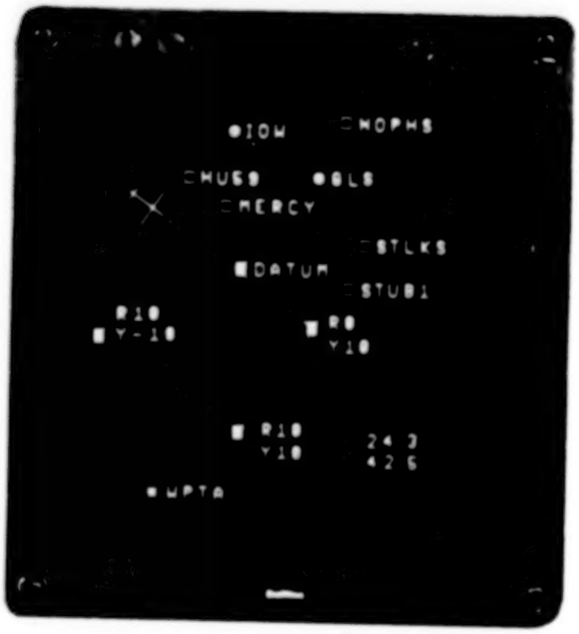
● IOW
☐ NOPHS
☐ HUSS
● BLS
☐ MERCY
☐ STLKS
■ DATUM
☐ STUB1
R10
■ Y-10
■ R8
Y10
■ R10
Y10
24 3
42 6
■ WPTA

FIG. 13

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N85 14816

D10

INTEGRATED COCKPIT DESIGN FOR THE ARMY HELICOPTER IMPROVEMENT PROGRAM

T.Drennen
Sperry

and

B. Bowen
Bell Helicopter Textron, Inc.

In 1981, the team of Bell Helicopter-Textron, Inc. (BHTI), Sperry, McDonnell-Douglas, and Northrop was awarded the contract for full scale development of the OH-58D Aeroscout for the Army Helicopter Improvement Program (AHIP). The team leader, BHTI, is modifying the existing OH-58A aircraft engine, transmission, and rotor systems for improved aircraft performance. They are also integrating the mission avionics. Sperry is providing the advanced control-display subsystem (CDS). McDonnell-Douglas is developing the Mast Mounted Sight (MMS) with Northop providing the TV and FLIR system.

ARMY HELICOPTER IMPROVEMENT PROGRAM

OH-58A Airframe supplied by the U.S. Army

FIG. 1

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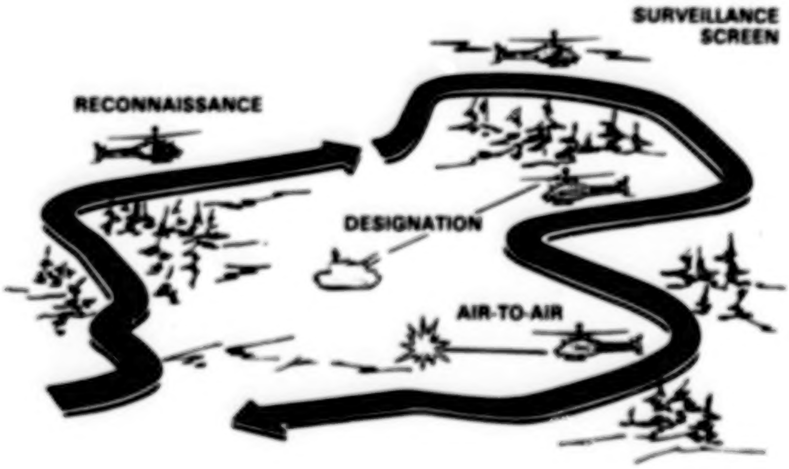
The main AHIP mission is to navigate precisely, locate targets accurately, communicate their position to other battlefield elements, and to designate them for laser guided weapons. The onboard navigation and mast-mounted sight (MMS) avionics enable accurate tracking of current aircraft position and subsequent target location. The multiple radio suite and target handoff systems enable quick, flexible communication of targeting data to attack helicopters, artillery, and battlefield command elements. The MMS laser designator permits precise pin-pointing of targets for laser guided weapons such as Hellfire and Copperhead. Provisions are also being made for air-to-air defense capability.

AHIP MISSION



- Navigate
- Locate
- Communicate
- Designate

FIG. 2

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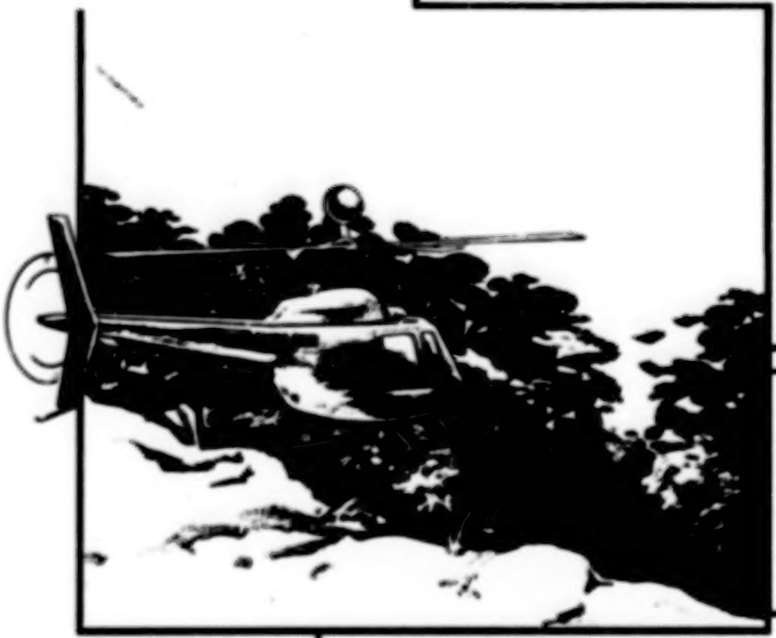
The AHIP mission scenarios call for nap-of-the-Earth (NOE) flight to minimize exposure in high threat areas. Low altitude and slow ground speeds are used in both day and night VFR conditions. The close proximity to the ground and obstacles require high pilot concentration for safe flight. Quick unmasking/masking maneuvers require rapid but stable aircraft response. Throughout the mission, precise navigation is required for accurate targeting.

MISSION ENVIRONMENT



- HIGH THREAT
- NAP OF THE EARTH (NOE)
  - 5 FT TO CLEAR OBSTACLES
  - 0 TO 60 KTS (AVERAGE 15 KTS IN WOODED AREAS)

- DAY AND NIGHT VFR
- QUICK MANEUVERS
- HIGH PILOT CONCENTRATION
- QUICK RESPONSE DEMANDS

THE AHIP AEROSCOUT MISSION SCENARIO

FIG. 3

The AHIP crewstation development was based on extensive mission/task analysis, function allocation, total system design, and test and verification. Detailed descriptions of the AHIP missions were prepared using realistic battlefield constraints and conditions. Timelines and task analyses were prepared based on the mission requirements and timeline limitations. Critical mission segments of high workload were identified. Function allocations were assigned between aircrew and avionics based on state-of-the-art capabilities. Avionics/cockpit designs were then developed based on the results of the previous tasks. Those concepts were then tested and verified via analyses, mockup, and part-task evaluations.

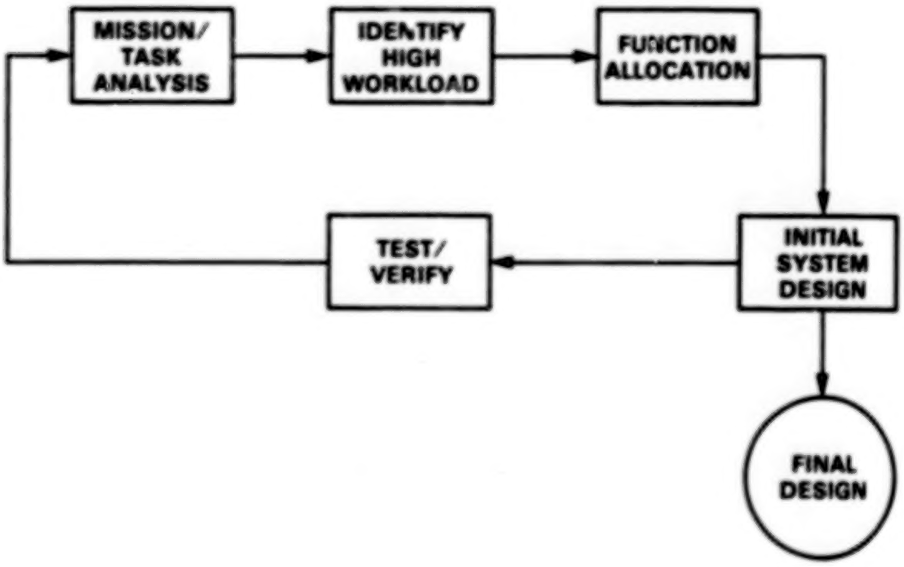

MISSION/
TASK
ANALYSIS
IDENTIFY
HIGH
WORKLOAD
FUNCTION
ALLOCATION
TEST/
VERIFY
INITIAL
SYSTEM
DESIGN
FINAL
DESIGN

FIG. 4

The information/command flow for AHIP was determined. Each type of information and control was identified along with the signal source and receiver. After linking these signals/data flows, the functions were allocated to specific subsystems.

AHIP SYSTEM INTEGRATION

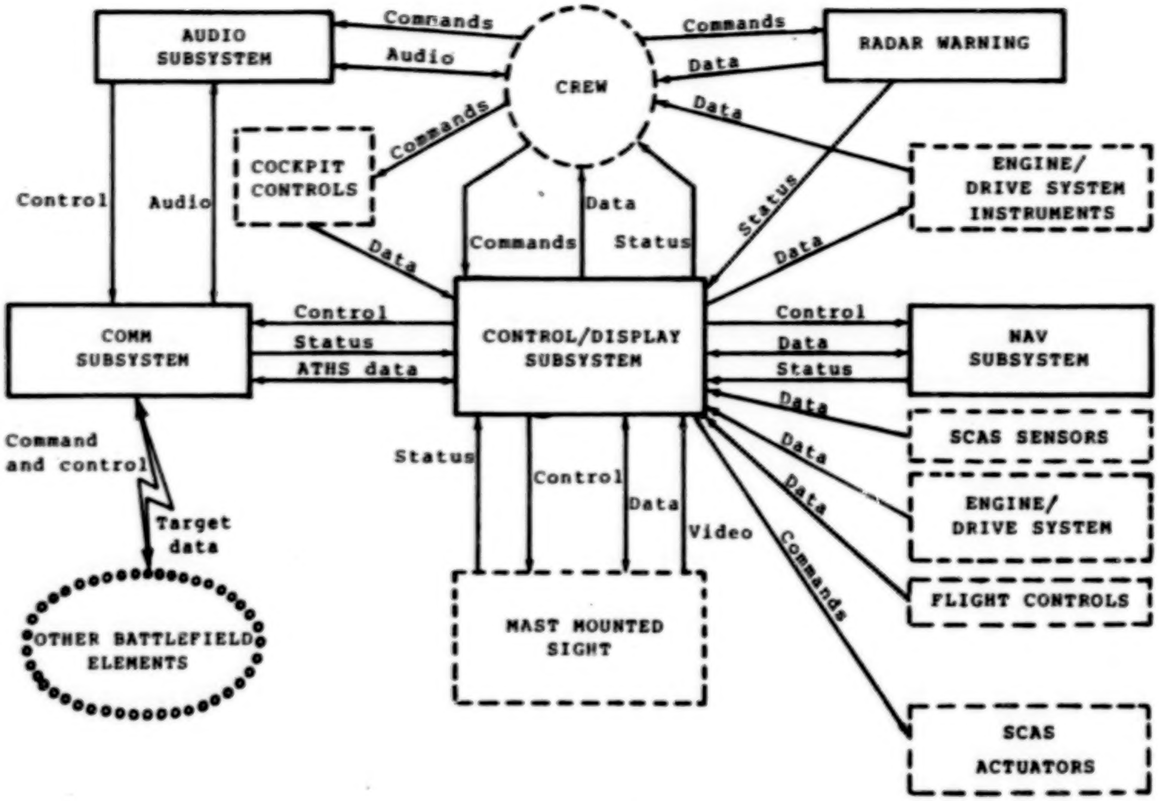

AUDIO SUBSYSTEM
Commands
Audio
CREW
Commands
Data
RADAR WARNING
Commands
COCKPIT CONTROLS
Data
ENGINE/ DRIVE SYSTEM INSTRUMENTS
Control
Audio
Data
Commands
Status
Status
Data
Data
COMM SUBSYSTEM
Control
Status
ATHS data
CONTROL/DISPLAY SUBSYSTEM
Control
Data
Status
NAV SUBSYSTEM
Data
SCAS SENSORS
Data
ENGINE/ DRIVE SYSTEM
Data
FLIGHT CONTROLS
Command and control
Target data
Status
Control
Data
Video
Commands
OTHER BATTLEFIELD ELEMENTS
MAST MOUNTED SIGHT
SCAS ACTUATORS

FIG. 5

The preliminary analyses indicated significantly high crew workload. To reduce the workload, the function allocation process was based on five levels of crew interaction. Those functions that could be automated were assigned to specific processors with monitoring and mode control allocated to the crew. If automation was not practical, computer assistance was considered. If control function was required during critical mission segments, "hands on" control on the collective or cyclic stick grip was assigned. Other control/display functions were then allocated to the multifunction displays (MFDS) except for high frequency of use functions, safety of flight functions, and functions associated with government furnished equipment (GFE). These functions used dedicated controls and displays.

FUNCTIONAL ALLOCATION

- Automate
- Computer Assist
- "Hands On"
- MFD Control/Display
- Dedicated Control/Display

FIG. 6

The AHIP cockpit design was driven to an integrated control/display approach by several factors. The threat capabilities dictated the "nap-of-the-Earth" (NOE) flgiht requirements and the mission requirements. The mission requirements called for scout functions in both day and night conditions. These factors, in turn, led to a potential high crew workload. The NOE environment also drove the need for excellent external visibility. The high workload condition caused the need for the automated and "hands on" features and reduced visual scanning with the MFDs. The avionics requirements to meet the mission was limited by the existing aircraft structural and performance characteristics and resultant space, weight, and power restrictions. These limitations and the night operations requirement led to the use of night vision goggles. The combination of these requirements and limitations dictated an integrated control/display approach using multifunction displays and controls.

AHIP DESIGN DRIVERS

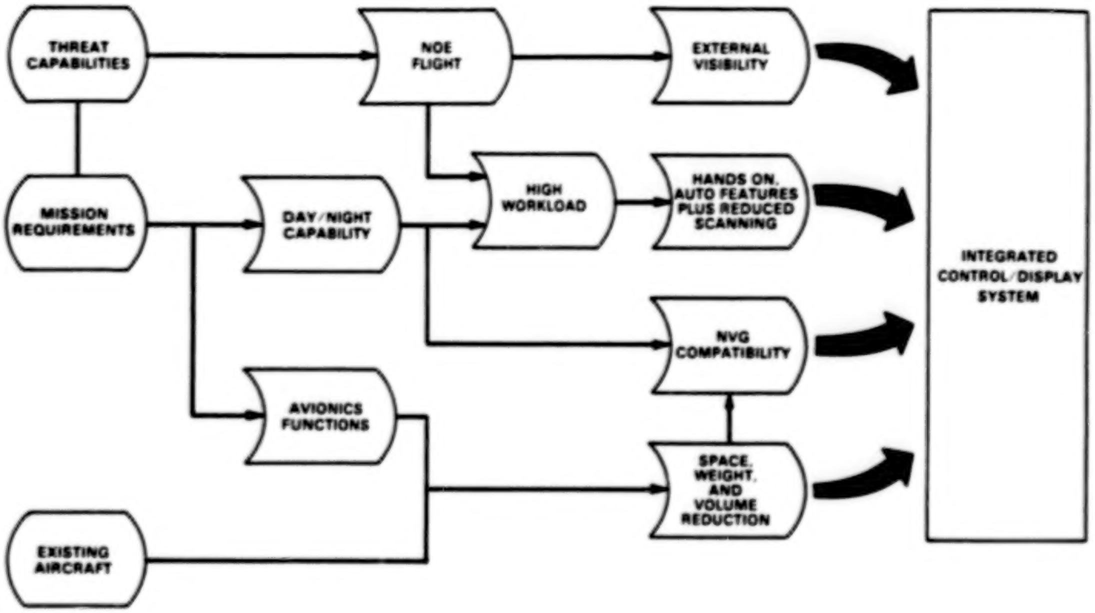

THREAT CAPABILITIES
NOE FLIGHT
EXTERNAL VISIBILITY
MISSION REQUIREMENTS
DAY/NIGHT CAPABILITY
HIGH WORKLOAD
HANDS ON, AUTO FEATURES PLUS REDUCED SCANNING
INTEGRATED CONTROL/DISPLAY SYSTEM
NVG COMPATIBILITY
AVIONICS FUNCTIONS
SPACE, WEIGHT, AND VOLUME REDUCTION
EXISTING AIRCRAFT

FIG. 7

The resultant cockpit design provides flexible, multi-CRT cockpit displays. These multifunction displays (MFDs) enabled the instrument panel to be reduced for improved external visibility. Night Vision Goggles (NVG) compatability was achieved through the use of P-43 phosphors on the MFDs, electroluminescent panel lighting and selective filters for incandescent lights and radar warning display. The AHIP blue-green lighting provides excellent low light level readability with minimal effect on ANVIS NVGS.

Vertical scale and digital readouts integrate engine, transmission, rotor electrical, and aircraft systems data. The remote frequency display (RFD) integrates the communications data for all five radios. The multifunction keyboard enables flexible data entry.

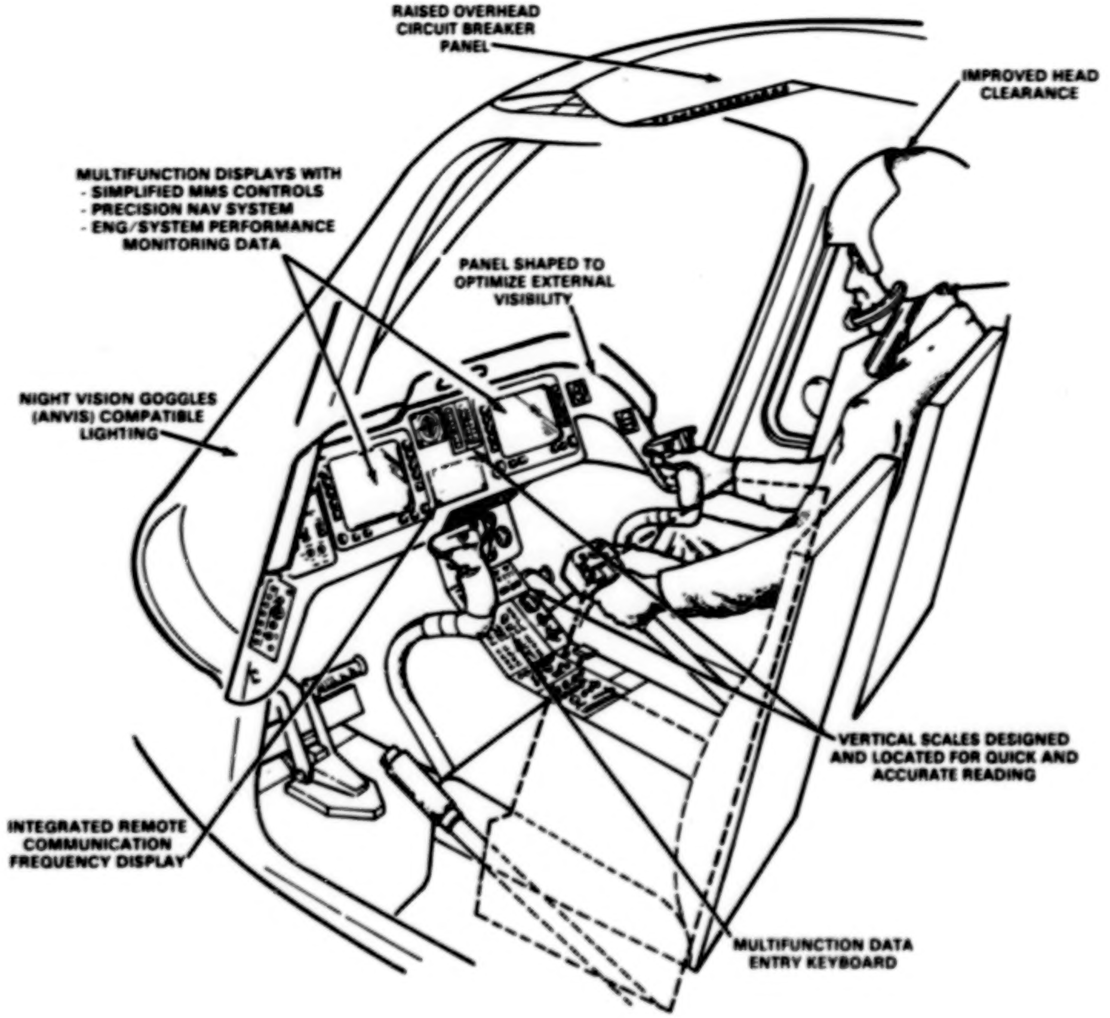

RAISED OVERHEAD CIRCUIT BREAKER PANEL
IMPROVED HEAD CLEARANCE
MULTIFUNCTION DISPLAYS WITH
- SIMPLIFIED MMS CONTROLS
- PRECISION NAV SYSTEM
- ENG/SYSTEM PERFORMANCE MONITORING DATA
PANEL SHAPED TO OPTIMIZE EXTERNAL VISIBILITY
NIGHT VISION GOGGLES (ANVIS) COMPATIBLE LIGHTING
VERTICAL SCALES DESIGNED AND LOCATED FOR QUICK AND ACCURATE READING
INTEGRATED REMOTE COMMUNICATION FREQUENCY DISPLAY
MULTIFUNCTION DATA ENTRY KEYBOARD

FIG. 8

The AHIP instrument panel and center console have few conventional controls and displays. The MFDs provide for most of the control and display functions. The standby instruments consist of attitude, airspeed and altitude indicators. RPM, torque, and turbine gas temperature information are shown on the vertical scales on the main instrument panel. Additional vertical scale and digital readouts for additional aircraft systems data are located below the standby instruments. The center console has only six panels, the keyboard, SCAS panel, and four government furnished equipment panels (ICS, IFF, radar warning and compass control).

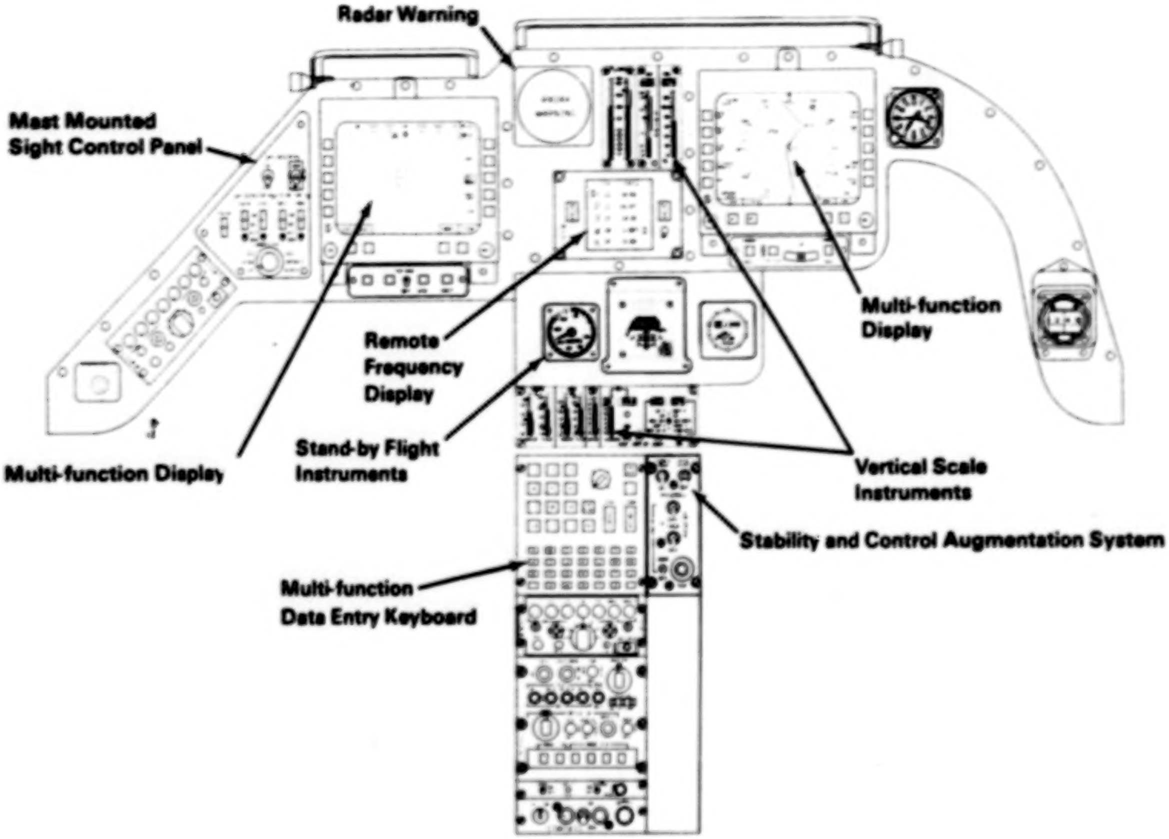

Radar Warning
Mast Mounted Sight Control Panel
Multi-function Display
Remote Frequency Display
Stand-by Flight Instruments
Multi-function Data Entry Keyboard
Multi-function Display
Vertical Scale Instruments
Stability and Control Augmentation System

FIG. 9

The MFDs provide flexible control and display of most of the aircraft and avionics parameters. The MFDs consist of 4.8" x 6.4" monochromatic, 875 line raster video displays. Manual brightness and contrast controls are incorporated along with an auto contrast feature. The use of P-43 phosphor and narrow band filter enable sunlight readability and NVG compatability. The fourteen MFD line select key functions (five on the left, five on the right, and four on the bottom side) are annunciated on the CRT. The four bottom switches are used for selecting the main display modes of vertical situation, horizontal situation, communication control, and mast mounted sight displays. These modes can also be selected via a four way switch on the pilot's cyclic stick grip.

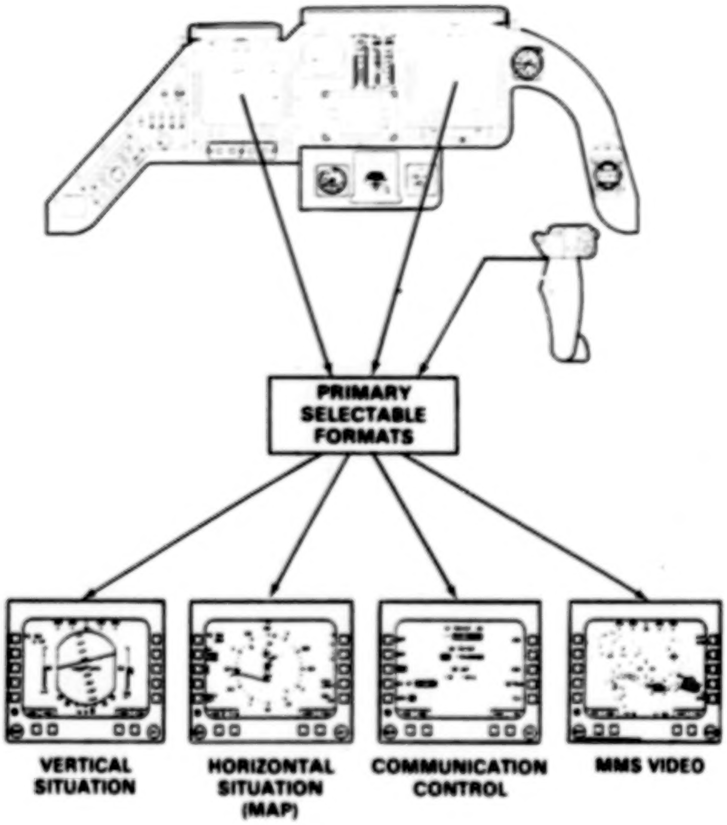

PRIMARY
SELECTABLE
FORMATS
VERTICAL
SITUATION
HORIZONTAL
SITUATION
(MAP)
COMMUNICATION
CONTROL
MMS VIDEO

FIG. 10

The MFDs provide information and control of most of the aircraft systems and replace many conventional instruments and panels. The VSD is the primary flight format replacing the ADI, altimeter (barometric and radar), airspeed indicator, vertical speed indicator, and radio magnetic indicator and distance to go, waypoint and present position readouts. The HSD is the primary navigation display, graphically showing present position, waypoints, course lines, and other related data and control functions. Up to 40 waypoints can be stored in the CDS. The MMS provides the MMS video and various readouts and mode controls. The COM pages supplement the RFD for control of the communications radios. The MFDs provide additional data such as caution, warning, and advisory readouts on both displays regardless of display mode.Automated Target Handoff System (ATHS) pages are accessed through a dedicated switch below the CPO MFD.

MULTIFUNCTION DISPLAY (MFD) FORMATS

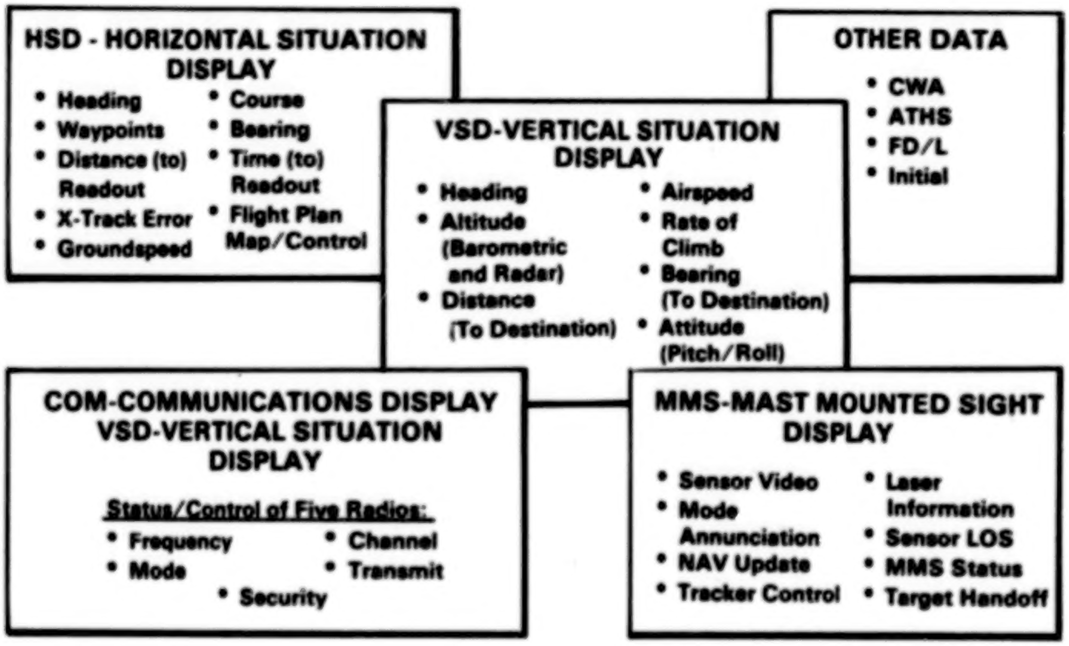

HSD - HORIZONTAL SITUATION DISPLAY
• Heading
• Waypoints
• Distance (to) Readout
• X-Track Error
• Groundspeed
• Course
• Bearing
• Time (to) Readout
• Flight Plan Map/Control
OTHER DATA
• CWA
• ATHS
• FD/L
• Initial
VSD-VERTICAL SITUATION DISPLAY
• Heading
• Altitude (Barometric and Radar)
• Distance (To Destination)
• Airspeed
• Rate of Climb
• Bearing (To Destination)
• Attitude (Pitch/Roll)
COM-COMMUNICATIONS DISPLAY VSD-VERTICAL SITUATION DISPLAY
Status/Control of Five Radios:
• Frequency
• Mode
• Channel
• Transmit
• Security
MMS-MAST MOUNTED SIGHT DISPLAY
• Sensor Video
• Mode Annunciation
• NAV Update
• Tracker Control
• Laser Information
• Sensor LOS
• MMS Status
• Target Handoff

FIG. 11

The pilot's collective stick grip contains controls for the selection of radios and radio channels for "hands on" operation. The radio selector switch permits selection of any of the five radios with a single button press. The channel select switch controls channel number selection (up or down), call up of the frequency data page on the MFD, or making the keyboard active for a new frequency entry. Thirty frequency channels can be stored in the CDS for direct use.

Inclusion of those functions was based on the criticality and frequency of comm tasks for AHIP. Typical engine and searchlight functions are also provided.

AHIP PILOT'S COLLECTIVE

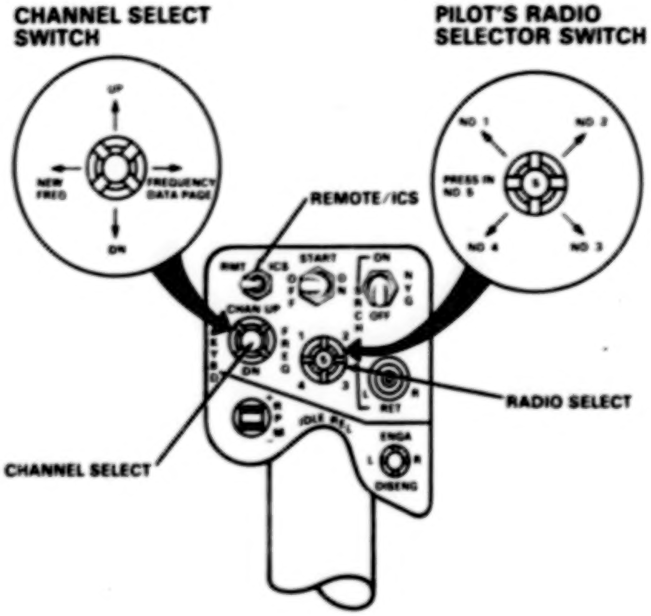
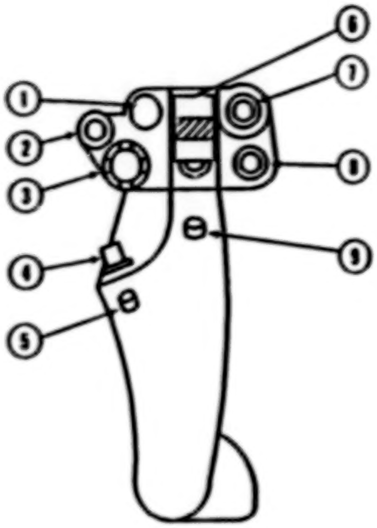

CHANNEL SELECT SWITCH
PILOT'S RADIO SELECTOR SWITCH
UP
NEW FREQ
FREQUENCY DATA PAGE
DN
NO 1
NO 2
PRESS IN NO 5
NO 4
NO 3
REMOTE/ICS
RMT
ICS
START
OFF
ON
ON
NYG
SRCH
OFF
CHAN UP
KEYBD
FREQ
DN
1
2
5
4
3
L
R
RET
RADIO SELECT
RPM
IDLE REL
ENGA
L
R
DISENG
CHANNEL SELECT

FIG. 12

In addition to selected flight controls, the pilot grip incorporates controls necessary to select display formats, select and fire missiles and to override CPO MMS controls. The pilot MMS override switch slews the MMS LOS to the forward position (relative to the nose of the aircraft).

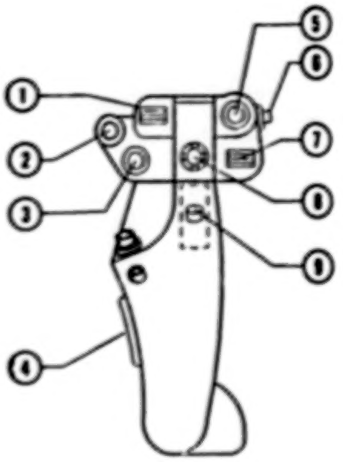


1. Spare
2. Bob-Up. For hover symbology. See page
3. Display Select.
4. Force Trim. Momentary release.
5. SCAS Release. Disengages SCAS.
6. Missile Fire
7. Pilot MMS Override
8. Missile Select
9. Missile Uncage

PILOT GRIP

FIG. 13

In addition to selected flight controls, the CPO grip incorporates all controls necessary to engage the basic operating mode, select more refined tracking modes, manually slew the line-of-sight control and select the MMS options appropriate to the operational situation. The CPO stick is normally locked out so it will not interfere with pilot flight control.



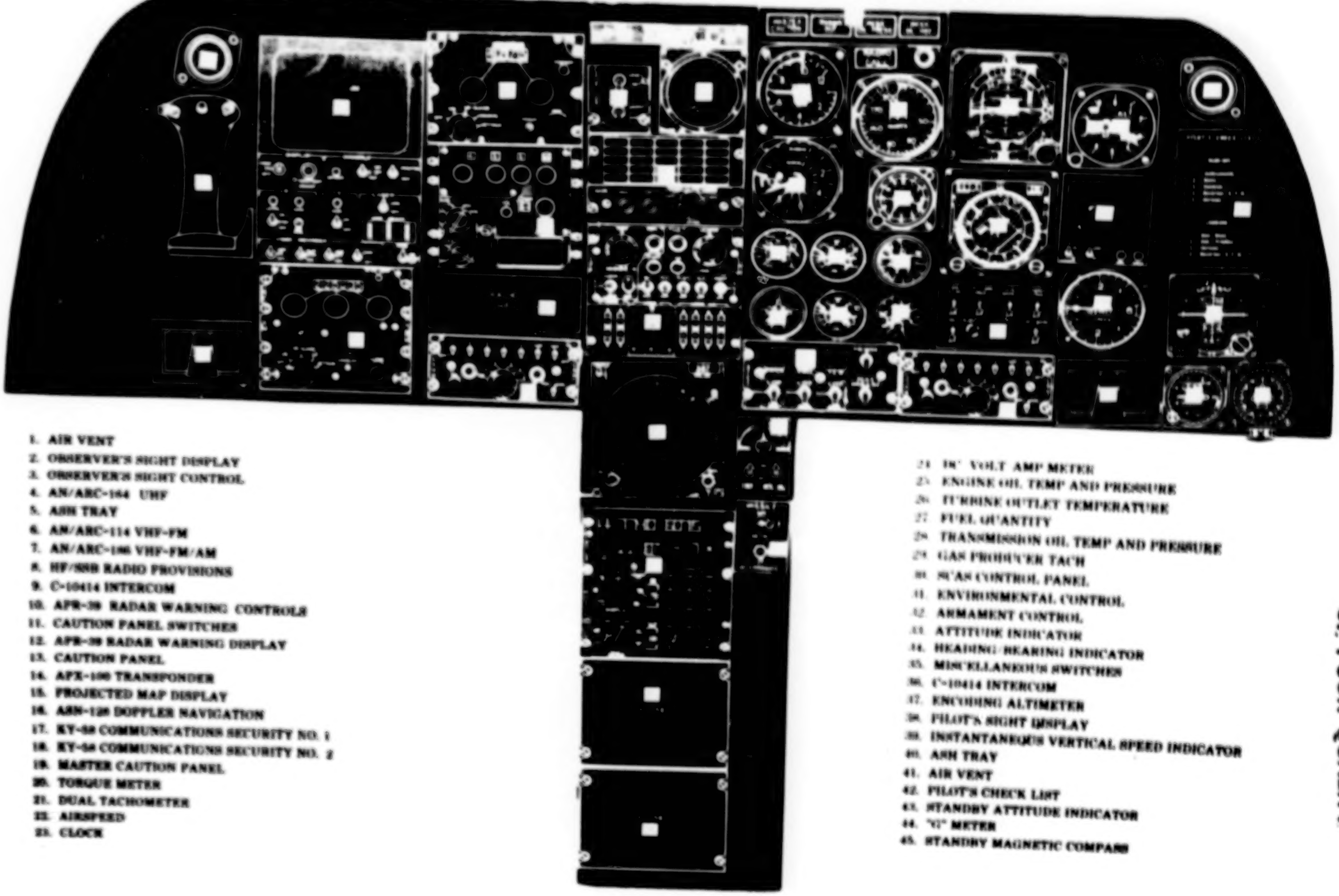
1. Select wide or narrow field of view and zoom 2X or 4X when TIS is selected
2. Laser fire for navigation update or target designate.
3. Select area track.
4. Select point track.
5. Change from TIS to TV or from TV to TIS.
6. Engage/disengage stop-action feature.
7. Prepare for navigation update.
8. Manually adjust LOS for target acquisition or laser hit point.
9. Engage basic operating mode.

CPO GRIP

FIG. 14

A "non-integrated" approach using "off-the-shelf" hardware yielded a significantly larger instrument panel and number of dedicated instruments. These instruments would provide less information in an inflexible format with little preprocessing of the information.

NON INTEGRATED SCOUT



1. AIR VENT
2. OBSERVER'S SIGHT DISPLAY
3. OBSERVER'S SIGHT CONTROL
4. AN/ARC-164 UHF
5. ASH TRAY
6. AN/ARC-114 VHF-FM
7. AN/ARC-186 VHF-FM/AM
8. HF/SSB RADIO PROVISIONS
9. C-10414 INTERCOM
10. APR-39 RADAR WARNING CONTROLS
11. CAUTION PANEL SWITCHES
12. APR-39 RADAR WARNING DISPLAY
13. CAUTION PANEL
14. APX-100 TRANSPONDER
15. PROJECTED MAP DISPLAY
16. ASN-128 DOPPLER NAVIGATION
17. KY-58 COMMUNICATIONS SECURITY NO. 1
18. KY-58 COMMUNICATIONS SECURITY NO. 2
19. MASTER CAUTION PANEL
20. TORQUE METER
21. DUAL TACHOMETER
22. AIRSPEED
23. CLOCK
24. DC VOLT AMP METER
25. ENGINE OIL TEMP AND PRESSURE
26. TURBINE OUTLET TEMPERATURE
27. FUEL QUANTITY
28. TRANSMISSION OIL TEMP AND PRESSURE
29. GAS PRODUCER TACH
30. SCAS CONTROL PANEL
31. ENVIRONMENTAL CONTROL
32. ARMAMENT CONTROL
33. ATTITUDE INDICATOR
34. HEADING/BEARING INDICATOR
35. MISCELLANEOUS SWITCHES
36. C-10414 INTERCOM
37. ENCODING ALTIMETER
38. PILOT'S SIGHT DISPLAY
39. INSTANTANEOUS VERTICAL SPEED INDICATOR
40. ASH TRAY
41. AIR VENT
42. PILOT'S CHECK LIST
43. STANDBY ATTITUDE INDICATOR
44. "G" METER
45. STANDBY MAGNETIC COMPASS

FIG. 15

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The impact of system complexity and lack of control/display integration is shown in the instrument panel outlines. As more and more avionics have been added to the OH-58, the instrument panel grew which reduced external visibility. By using the MFDs, vertical scales and limited dedicated instruments, the forward panel was shaped to follow the aircraft structure to maximize the external visibility.

INTEGRATED COCKPIT SYSTEMS EFFECT ON PANEL GROWTH

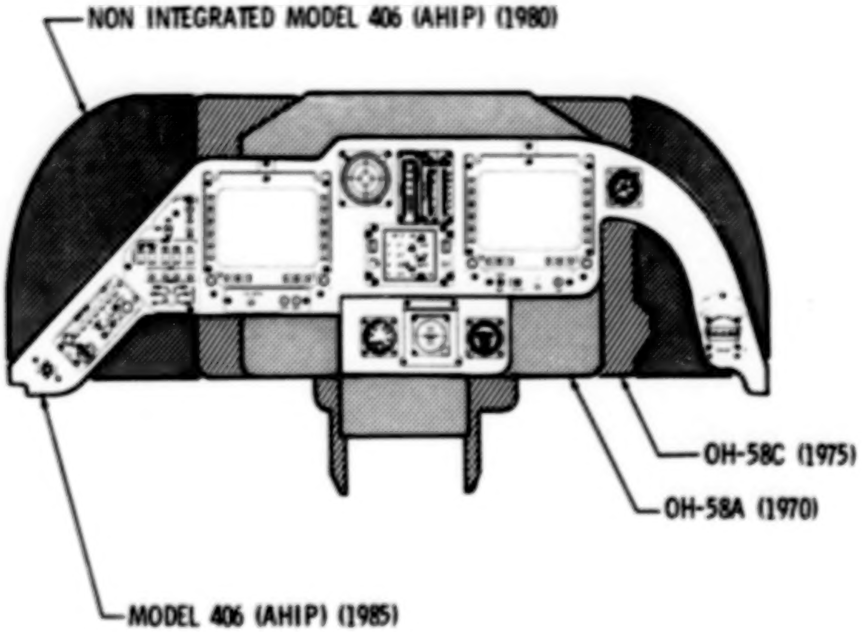

NON INTEGRATED MODEL 406 (AHIP) (1980)
OH-58C (1975)
OH-58A (1970)
MODEL 406 (AHIP) (1985)

FIG. 16

The current AHIP design significantly reduces the number of instruments/panels and panel space from both the "non-integrated" scout concept and the existing OH-58C.

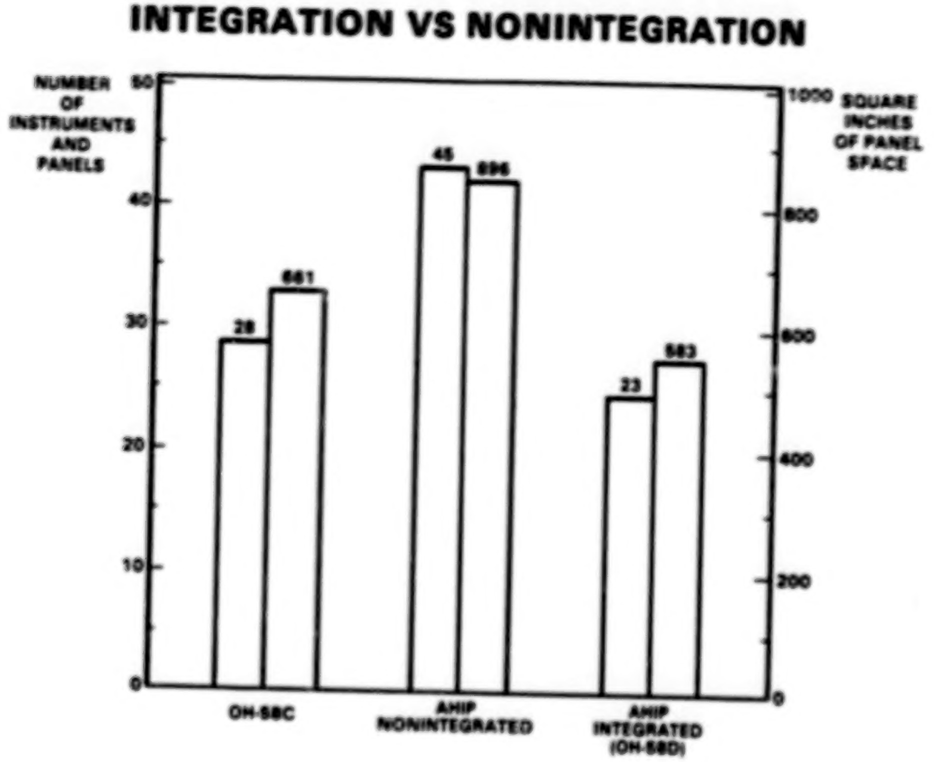
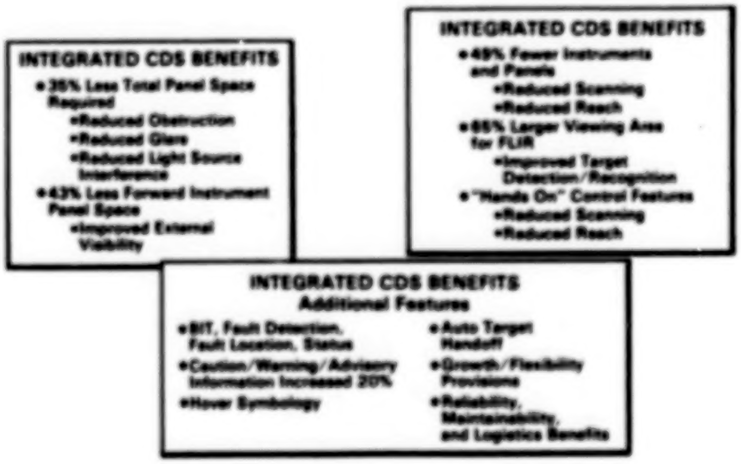


FIG. 17

The reduced instrument panel space increases external visibility. The reduced center, aft and overhead panels limits stray light in the cockpit, thus enhancing external visibility. The use of large CRTs provides significantly larger viewing area for FLIR imagery than the non-integrated scout approach for improved target detection and recognition. The integrated CDS approach reduces visual scanning and reach requirements. The flexibility of the integrated CDS incorporates built-in-test, fault/detection and location and system status data for ease of maintenance. Most changes can be handled without major hardware modifications. More caution, warning, and advisory information can be provided with more preprocessing to reduce false alarms and relieve aircrew cognitive workload. The reduced number of line replaceable units significantly improves maintainability, reliability, and logistic requirements for the aircraft. The "hands on" controls reduces the workload associated with finding and manipulating critical control functions.

THE INTEGRATED CONTROL/DISPLAY SYSTEM (CDS)



INTEGRATED CDS BENEFITS

- 35% Less Total Panel Space Required
  - Reduced Obstruction
  - Reduced Glare
  - Reduced Light Source Interference
- 43% Less Forward Instrument Panel Space
  - Improved External Visibility

INTEGRATED CDS BENEFITS

- 49% Fewer Instruments and Panels
  - Reduced Scanning
  - Reduced Reach
- 65% Larger Viewing Area for FLIR
  - Improved Target Detection/Recognition
- "Hands On" Control Features
  - Reduced Scanning
  - Reduced Reach

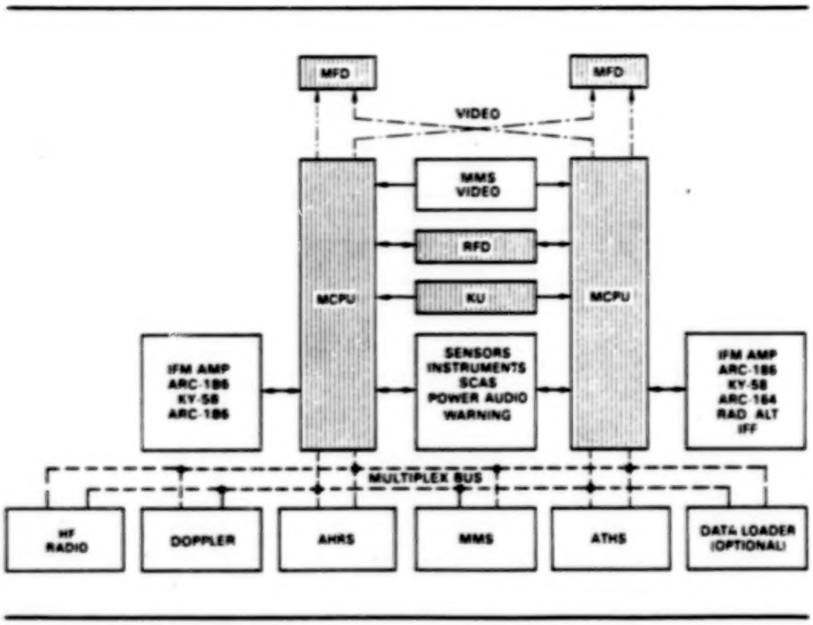
INTEGRATED CDS BENEFITS
Additional Features

- BIT, Fault Detection, Fault Location, Status
- Caution/Warning/Advisory Information Increased 20%
- Hover Symbology
- Auto Target Handoff
- Growth/Flexibility Provisions
- Reliability, Maintainability, and Logistics Benefits

FIG. 18

The unique control-display features of the AHIP cockpit result from the capability to control, receive, and display information about the various avionics and aircraft systems. A MIL-STD-1553B multiplex data bus, under control of a Master Controller Processor Unit (MCPU), provides a lightweight, flexible means to communicate and control various mission avionics. The MCPUs also directly interface to the Stability Control Augmentation System (SCAS), COM radios and various aircraft systems and instruments. With these available interfaces, the processing capabilities of the MCPUs can be applied to automate or enhance many aircrew tasks. The symbol generator function of the MCPUs also drives the MFDs.

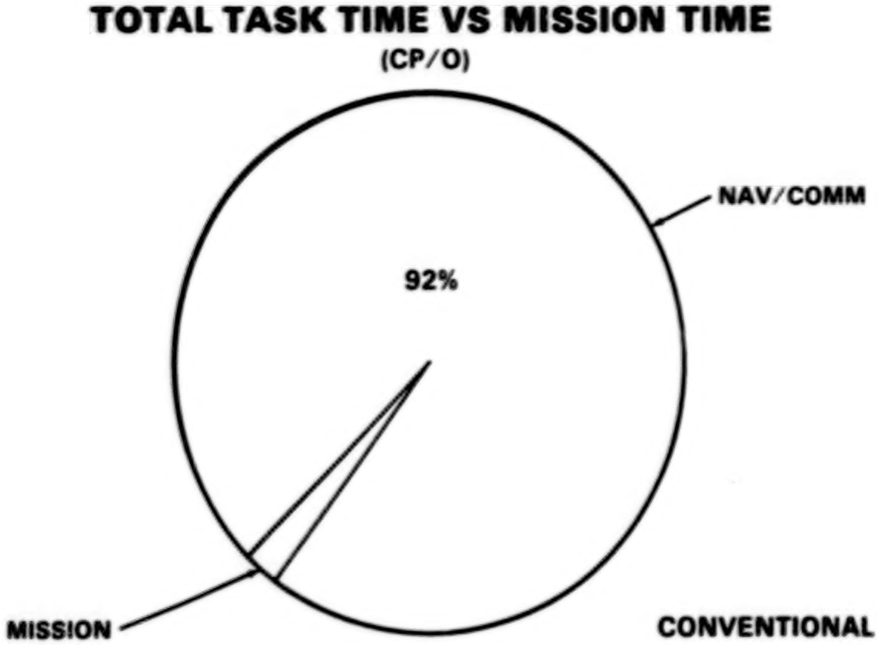
OH-58D AHIP System Overview


MFD
MFD
VIDEO
MCPU
MMS VIDEO
RFD
KU
SENSORS INSTRUMENTS SCAS POWER AUDIO WARNING
MCPU
IFM AMP ARC-186 KY-58 ARC-186
IFM AMP ARC-186 KY-58 ARC-164 RAD ALT IFF
MULTIPLEX BUS
HF RADIO
DOPPLER
AHRS
MMS
ATHS
DATA LOADER (OPTIONAL)

- Operation and Control of the Digital Data Bus
- Control and Display of Mast Mounted Sight Video/Data
- Control and Display of Navigation Data
- Flight Planning Navigation Data Storage, and Map Generation
- Caution, Warning, and Advisory System Management
- Generation of Horizontal/Vertical Situation Displays
- SCAS Computation and Control
- Communications Management

FIG. 19

Aircrew task/workload analyses show that the integrated CDS for AHIP significantly improves the time available for mission-related tasks. A conventional scout aircraft cockpit layout demands 92% of CPO time for navigation and communication functions during NOE flight. Only eight percent of available time can be used for aircraft system monitoring. Crew overload would result if target detection and identification tasks were added.



TOTAL TASK TIME VS MISSION TIME
(CP/O)

FIG. 20

Through use of the integrated CDS, NAV/COM task times are significantly reduced due to automation and ease of comm control. This time can then be used for target detection, identification, and designation with the MMS and other mission-related tasks such as systems, obstacle, and threat monitoring. This leads to performing the mission more successfully and safely.

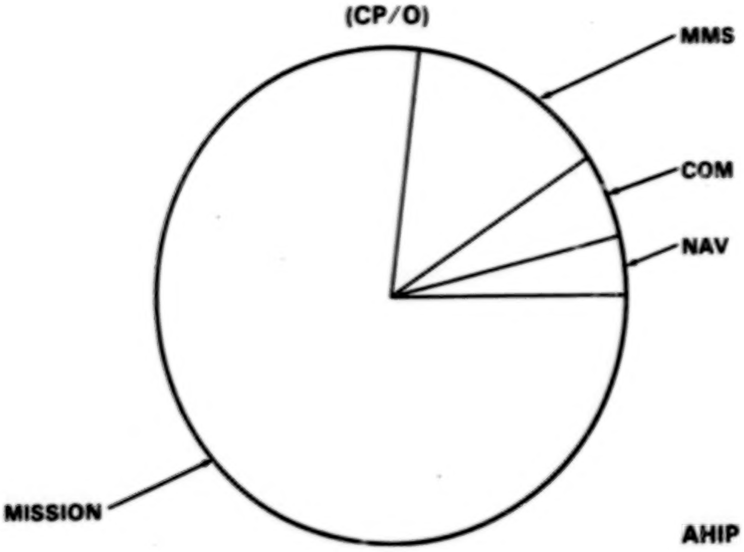


FIG. 21

The development of the AHIP cockpit pointed out several critical decisions in determining integrated control operational requirements (what needs to be seen, when, by whom, and under what conditions). Display size should provide maximum visual arc for target detection and symbology legibility.

The number of line select keys should be dependent on display moding architecture. Also, the number of line selects on a given side or group should be limited to four or five to minimize the requirement to "read" the legends as opposed to using positional cueing. Past studies have indicated that the levels of indenture (or "paging") and the number of line selects can significantly impact the system utility. Seventy to eighty percent of the AHIP pages needed at a given time can be accessed through a single button press, 80 - 90% with two button presses, and 95 - 98% within three button presses. Efforts should be made to minimize the need for keyboard data entry in flight, particularly NOE.

The need for a full alphanumeric or multi-mode keyboard layout must consider the two to three-fold increase in data entry time with a multi-mode approach. The need for a "scratch pad" display area on the keyboard or MFD must consider frequency of use, length of data strings, and visual angle between the keyboard and display. Unless very long data strings are frequently entered and the MFD keyboard distance is great, a "scratch pad" display in the keyboard is not typically required.

Selection of "hands on" functions must be limited to critical mission or safety of flight functions. The multiplex CDS provides the capability for many "hands on" functions, but they must be restricted to keep from placing excessive manual manipulation on the grips, i.e., the "piccolo player" syndrome.

CDS DESIGN DECISIONS

- Number & Size of MFDs
- Number of Line Select Keys
- Levels of Indenture/Page Access
- Keyboard Configuration
  - Partial/Full Alphanumerics
  - "Scratch Pad"
- "Hands On" Functions

FIG. 22

The cockpit concepts for AHIP will enable the OH-58D aircrew to perform their multi-missions more effectively and more safely than previous Army scout helicopters. The versatility and flexibility of the AHIP Control Display System (CDS) will be able to accommodate growth and future improvements with minimal impact. Many of the AHIP features can be applied to existing and future aircraft. That is one of the reasons why the AHIP systems architecture is the US army nearterm standard. By use of the integrated cockpit design for AHIP, Army aviation will be better able to meet their mission and aircrew needs.

FIG. 23

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HH-60D NIGHT HAWK HELICOPTER

BY

C. S. RICHARDSON
IBM CORP
FEDERAL SYSTEM DIVISION
OWEGO, NY

NASA AMES ADVANCED HELICOPTER
COCKPIT DESIGN WORKSHOP

JULY 26 - 28, 1983

AVIONICS TECHNOLOGY – SYSTEM CONCEPTS

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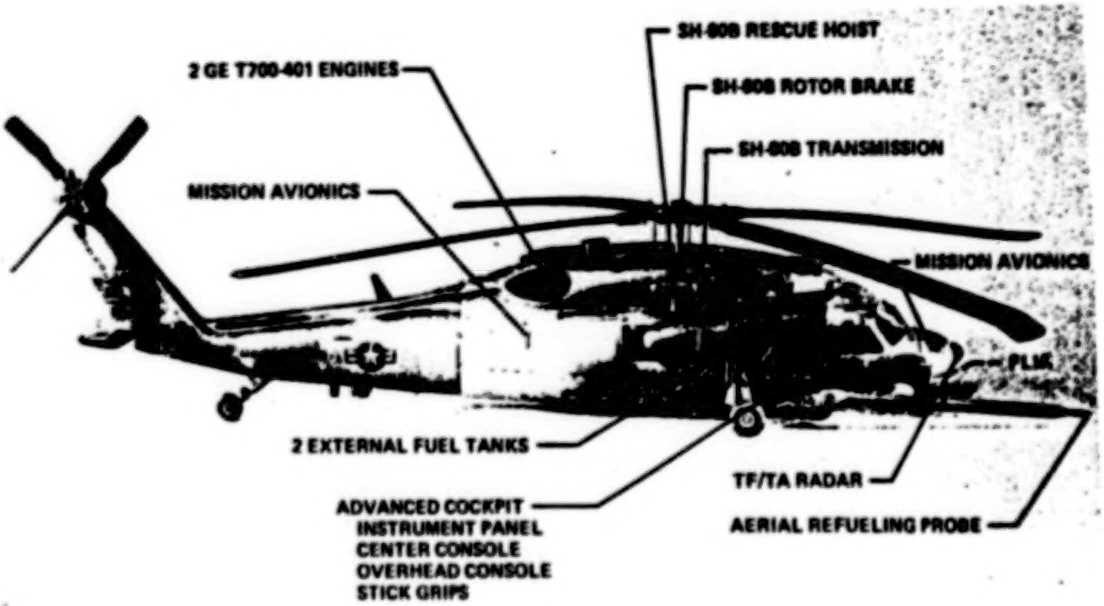
BRIEFING ON HH-60D NIGHTHAWK HELICOPTER WILL INCLUDE:

- A DESCRIPTION OF REQUIREMENTS
- A SYSTEM DESCRIPTION
- FUNDAMENTAL DEVELOPMENT ISSUES
- FUTURE IMPROVEMENTS

THE HH-60D MISSION REQUIREMENTS ARE FOR COMBAT SEARCH AND RESCUE (AEROSPACE RESCUE AND RECOVERY SERVICE USER BASED AT SCOTT AFB) AND SPECIAL OPERATIONS (SPECIAL OPERATIONS FORCES BASED AT HURLBURT AFB).

- NIGHT ADVERSE WEATHER AND HOSTILE AREA ENVIRONMENT
- 250 NAUTICAL MILE RADIUS
- 15 MINUTE SCRAMBLE ALERT
- 4000 FOOT, 95 DEGREE (F) MID MISSION HOVER
- AERIAL IN FLIGHT REFUELING


SH-60B RESCUE HOIST
2 GE T700-401 ENGINES
SH-60B ROTOR BRAKE
SH-60B TRANSMISSION
MISSION AVIONICS
MISSION AVIONICS
FLIR
2 EXTERNAL FUEL TANKS
TF/TA RADAR
ADVANCED COCKPIT
INSTRUMENT PANEL
CENTER CONSOLE
OVERHEAD CONSOLE
STICK GRIPS
AERIAL REFUELING PROBE

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BASIC AIRCRAFT IS UH-60A, CHOSEN FOR ITS EXCELLENT COMBAT SURVIVABILITY AND STATE OF THE ART RELIABILITY AND MAINTAINABILITY FEATURES.

UH-60A AIRFRAME IS MODIFIED BY SIKORSKY TO INCLUDE:

- SH-60B ENGINES AND TRANSMISSION FOR 10 PERCENT MORE POWER
- SH-60B RESCUE HOIST WITH 225 FOOT CABLE
- SH-60B ROTOR BRAKE
- TWO 230 GALLON EXTERNAL TANKS FOR INCREASED RANGE
- A NEW 117 GALLON INTERNAL FUEL TANK FOR INCREASED RANGE
- A NEW COMPOSITE MATERIAL, AERIAL REFUELING PROBE
- A 90 MINUTE RECONFIGURABLE CABIN (FROM RESCUE TO PERSONNEL TRANSPORT)

MODIFIED UH-60A AIRFRAME IS THEN GOVERNMENT SUPPLIED TO IBM IN OWEGO, NEW YORK WHERE IT IS FURTHER MODIFIED TO INCLUDE:

- ADDITION OF SPECIAL MISSION EQUIPMENT
- INSTALLATION OF A FORWARD LOOKING INFRARED TURRET
- INSTALLATION OF A MULTIMODE RADAR
- AN ADVANCED COCKPIT CONFIGURATION

MAJOR AVIONIC PIDS REQUIREMENTS

• MANUAL TF/TA	– 100 FT (MIN) CLEARANCE ALTITUDE – SIMULTANEOUS RADAR AND FLIR – PILOT/COPILOT ALTERNATE TASKS
• COCKPIT	– PILOT/COPILOT (OVERFLOW TO FLT ENGR) – 4 MPDs, 2 HMDs, 2 KEYBOARDS – NVG COMPATIBILITY
• NAVIGATION	– 0.6 NMI/HR (CEP) DOPPLER-INERTIAL – GPS (PROVISIONS)
• SURVIVOR LOCATION	– 10 FT (CEP) ESLE (PROVISIONS) – UHF/ADF, FLIR/NVG/VISUAL SEARCH
• DEFENSIVE	– RADAR WARNING (APR-39) – CM DISPENSER (M-130 CHAFF, FLARES) – IR JAMMER (ALQ-144 PROVISIONS)
• COMM/ INTERCOM	– UHF/VHF/HF (CLEAR/SECURE) – RADIO NAVAIDS, IFF, BEACONS
• PROCESSING/ DATA BUS	– MIL-STD-1750A, JOVIAL J73, – MIL-STD-1553B, NOTICE 1
• APP/HOVER	– VELOCITY-REFERENCED, SH-60B COUPLER

THE AIR FORCE PROVIDED A HH-60D SYSTEM SPECIFICATION TO BOTH IBM AND SIKORSKY. THIS SPECIFICATION INCLUDED THE FOLLOWING SPECIFIC AVIONIC NEEDS.

- A MANUAL TF/TA CAPABILITY OF FLIGHT 100 FEET OFF THE DECK AT SPEEDS TO 125 KNOTS TO MINIMIZE EXPOSURE TO ENEMY GROUND FIRE. IN ADDITION ALL CONTROLS HAD TO BE AVAILABLE TO BOTH PILOTS SO THEY COULD RELIEVE EACH OTHER DURING THIS STRESSFUL MISSION.

- COCKPIT WORK LOAD REDUCTION FEATURES TO ELIMINATE THE NEED FOR A FULL TIME FLIGHT ENGINEER. THE EQUIPMENT COMPLIMENT SHOWN ALSO REQUIRED COMPATIBILITY WITH BOTH GENERATION 2 AND 3 NIGHT VISION GOGGLES.

- A DOPPLER/INERTIAL NAVIGATION SYSTEM WAS SPECIFIED ALONG WITH BACK UP MODES OF PURE INERTIAL, DOPPLER/HEADING AND ATTITUDE REFERENCE, AIR MASS AND PROVISIONS FOR GLOBAL POSITIONING SATELLITE NAVIGATION.

- SURVIVOR LOCATION BY NORMAL MEANS AS WELL AS PROVISIONS FOR THE AIR FORCE DEVELOPMENT ELECTRONIC SURVIVOR LOCATION EQUIPMENT. THIS EQUIPMENT PROVIDES RANGE AND BEARING AS WELL AS IDENTIFICATION FOR UP TO SIX COOPERATIVE AN/PRC-112 RESCUE RADIOS SIMULTANEOUSLY.

- A DEFENSIVE SUBSYSTEM BASED UPON EXISTING EQUIPMENT BEING DEVELOPED AND USED BY THE U.S. ARMY.

- RADIO CAPABILITY BOTH SECURE AND CLEAR COVERING FOUR RADIO BANDS WITH FOUR RADIOS AND A SECURE INTERCOMMUNICATIONS SYSTEM - THE FIRST SUCH ON ANY HELICOPTER TO DATE. IN ADDITION A STANDARD SET OF RADIO NAVIGATION AIDS AND AN X BAND RADAR BEACON FOR RENDEZVOUS WITH THE REFUELING TANKER.

- A MIL-STD-1750A COMPUTER WAS SPECIFIED TO BE PROGRAMMED WITH 90 PERCENT JOVIAL J73 HIGH ORDER LANGUAGE AND A MIL-STD-1553B DUAL REDUNDANT DATA BUS WAS ALSO REQUIRED.

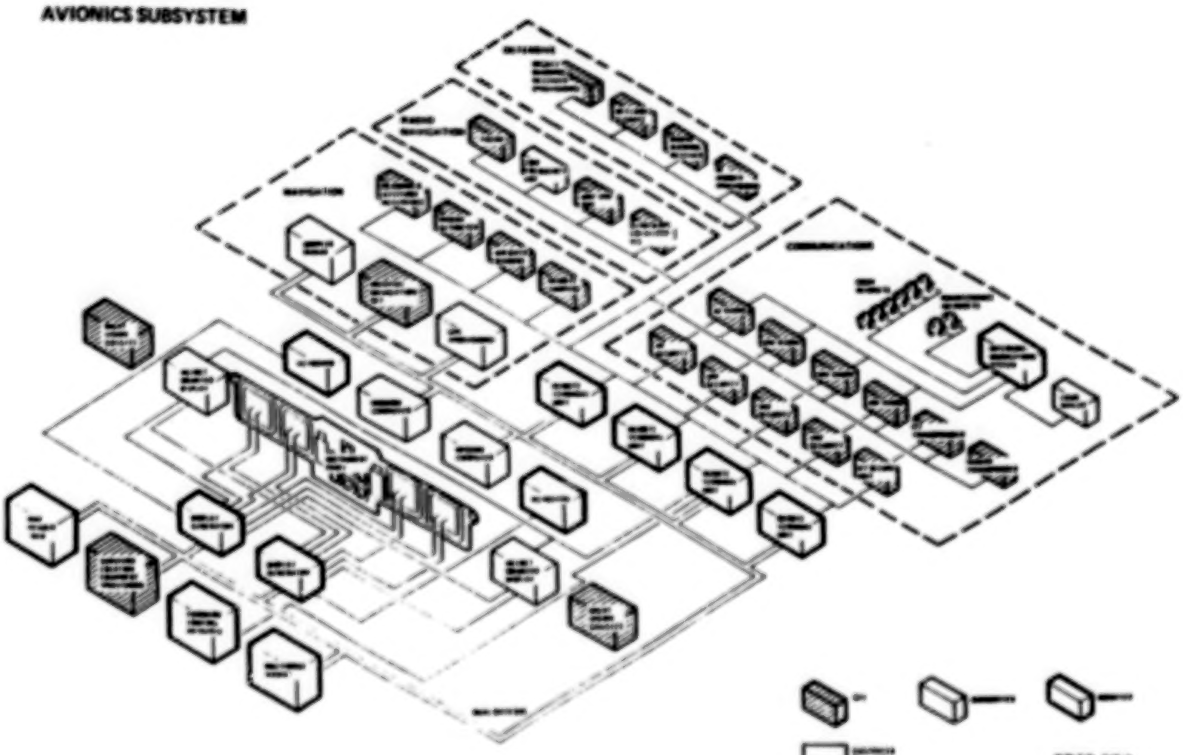
- THE AIR FORCE ALSO WANTED THE EXCELLENT APPROACH AND HOVER COUPLER DEVELOPED BY SIKORSKY FOR THE SH-60B HELICOPTER.

EQUIPMENT CONFIGURATION

- **Mission sensors**
- **Mission controls and displays**
- **Processing and interface**
- **Navigation**
- **Communications**
- **Radio navigation, identification**
- **Defensive**

THE AVIONIC EQUIPMENT CONFIGURATION PROVIDED IN RESPONSE TO THE AIR FORCE REQUIREMENTS CAN BE PARTITIONED INTO THE SEVEN SUBSYSTEMS LISTED.

AVIONICS SUBSYSTEM



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EQUIPMENT CHOSEN FOR THE HH-60D AVIONICS WERE SELECTED TO MINIMIZE DEVELOPMENT COST FOR HARDWARE. THIS WAS ACCOMPLISHED BY MAXIMIZING THE USE OF EXISTING, UNMODIFIED UNITS PREFERABLY IN SERVICE USE. WHERE UNMODIFIED UNITS COULD NOT BE FOUND TO MEET REQUIREMENTS, WE MODIFIED AVAILABLE DESIGNS. ONLY WHEN WE COULD NOT FIND AN ACCEPTABLE DESIGN DID WE GO TO A NEW DEVELOPMENT APPROACH. THERE IS ONLY ONE NEW UNIT IN THE HH-60D PROGRAM. IT IS A VIDEO REMOTE MAP READER UNIT BEING DEVELOPED BY BENDIX AS AN AIR FORCE STANDARD.

THIS MINIMUM HARDWARE DEVELOPMENT APPROACH ALLOWED US TO FOCUS ON THE COCKPIT INTEGRATION, THE CORE AVIONIC ARCHITECTURE, AND THE SOFTWARE DEVELOPMENT ACTIVITIES. IT IS IN THESE AREAS THAT THE HH-60D AVIONICS REPRESENT A MAJOR IMPROVEMENT OVER EXISTING HELICOPTER DESIGNS.

AVIONICS SUBSYSTEM ARCHITECTURE

- CORE INTEGRATING ELEMENTS
  - REDUNDANT/INTERCHANGEABLE/SURVIVABLE
  - NO SINGLE POINT FAILURE MODES FOR CRITICAL FUNCTIONS
  - STANDARDIZATION OF INTERFACES/SOFTWARE
  - SYNERGISTIC INTEGRATION OF AVIONICS, ENGINE INSTRUMENTS, CAUTION/WARNING/ADVISORY
- TWO IDENTICAL MISSION COMPUTERS
  - ALL MISSION PROCESSING CENTRALIZED
  - PRIMARY/BACKUP BUS CONTROL
  - MINIMUM COST APPROACH FOR FSD PHASE
  - BEST PERFORMANCE, GROWTH POTENTIAL
- TWO INTERCHANGEABLE DISPLAY ELECTRONICS UNITS
  - GRACEFUL DEGRADATION
  - VIDEO CROSS-STRAPPED
- FOUR REMOTE TERMINAL UNITS (COMMON DESIGN)
  - PHYSICAL SEPARATION
  - COMPLETE REDUNDANCY FOR ESSENTIAL FUNCTIONS
  - FUNCTIONAL REDUNDANCY FOR ALL FUNCTIONS
- FOUR MPDs, TWO HMDs, TWO KEYBOARDS
  - INTERCHANGEABLE, TWO MPDs PER PILOT
  - KEYBOARD/MPD DISCRETES CROSS-STRAPPED

5761-52A

THE CORE INTEGRATING ELEMENTS CONSIST OF FOUR MULTIPURPOSE DISPLAYS, TWO DISPLAY GENERATORS, TWO KEYBOARDS, FOUR REMOTE TERMINAL CONVERSION UNITS, AND TWO MISSION COMPUTERS. THESE ELEMENTS ARE INTEGRATED IN A MANNER TO PROVIDE THE LISTED FEATURES.

A TWO, TOTALLY REDUNDANT, MISSION COMPUTER ARCHITECTURE WAS CHOSEN BY IBM OVER THE AIR FORCE SPECIFIED SINGLE COMPUTER AND BACK UP BUS CONTROLLER REQUIREMENT. THIS APPROACH ENABLES THE AIR CREW TO CONTINUE THE MISSION IF A COMPUTER FAILS WITHOUT ANY LOSS OF FUNCTION. WE DISCOVERED THAT THIS APPROACH WAS NOT ONLY TECHNICALLY SUPERIOR BUT ACTUALLY LESS EXPENSIVE DURING DEVELOPMENT. DIGITAL COMPUTERS ARE BECOMING SMALLER, LIGHTER, MORE CAPABLE, AND SIGNIFICANTLY LESS COSTLY AS MAJOR TECHNOLOGY ADVANCES CONTINUE TO OCCUR.

EACH OF THE TWO DISPLAY GENERATORS PROVIDE OUTPUTS TO ALL FOUR MULTIPURPOSE DISPLAYS AND BOTH HELMET MOUNTED DISPLAYS. THE DISPLAY GENERATORS ARE TWO CHANNEL DEVICES AND SUPPLY TWO DIFFERENT DISPLAY FORMATS. SINCE A FULL UP SYSTEM INCLUDES TWO DISPLAY GENERATORS THERE ARE FOUR SEPARATE DISPLAY FORMATS AVAILABLE. IF A DISPLAY GENERATOR FAILS, THE SYSTEM WILL AUTOMATICALLY RECOVER TO PROVIDE THE TWO FORMATS SELECTED BY THE PILOT TO ALL DISPLAYS.

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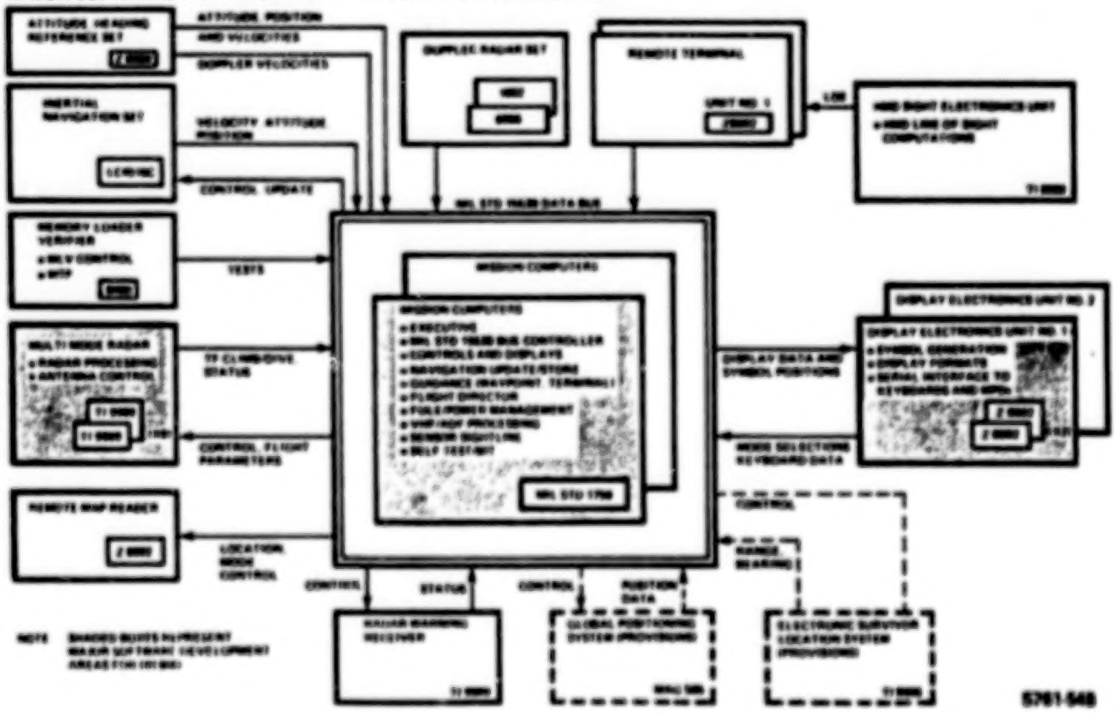
MAJOR SOFTWARE PARTITIONING OF HH-60D AVIONICS SUBSYSTEM


ATTITUDE HEADING REFERENCE SET
ATTITUDE, POSITION AND VELOCITIES
DOPPLER VELOCITIES
INERTIAL NAVIGATION SET
VELOCITY, ATTITUDE POSITION
CONTROL UPDATE
DOPPLER RADAR SET
REMOTE TERMINAL
UNIT NO. 1
LOS
HMD SIGHT ELECTRONICS UNIT
• HMD LINE OF SIGHT COMPUTATIONS
TI 9900
MIL STD 1553B DATA BUS
MEMORY LOADER VERIFIER
• MLV CONTROL
• BIT
TESTS
MISSION COMPUTERS
MISSION COMPUTERS
• EXECUTIVE
• MIL STD 1553B BUS CONTROLLER
• CONTROLS AND DISPLAYS
• NAVIGATION UPDATE/STORE
• GUIDANCE (WAYPOINT, TERMINAL)
• FLIGHT DIRECTOR
• FUEL/POWER MANAGEMENT
• VHF/ADF PROCESSING
• SENSOR SIGHTLINE
• SELF TEST/BIT
MIL STD 1750
MULTI MODE RADAR
• RADAR PROCESSING
• ANTENNA CONTROL
TI 9900
TI 9900
TF CLIMB/DIVE STATUS
CONTROL, FLIGHT PARAMETERS
DISPLAY ELECTRONICS UNIT NO. 2
DISPLAY ELECTRONICS UNIT NO. 1
• SYMBOL GENERATION
• DISPLAY FORMATS
• SERIAL INTERFACE TO KEYBOARDS AND MPDs
Z 8002
Z 8002
DISPLAY DATA AND SYMBOL POSITIONS
MODE SELECTIONS KEYBOARD DATA
REMOTE MAP READER
Z 8002
LOCATION MODE CONTROL
CONTROL
RANGE, BEARING
CONTROLS
STATUS
CONTROL
POSITION DATA
RADAR WARNING RECEIVER
TI 9900
GLOBAL POSITIONING SYSTEM (PROVISIONS)
ELECTRONIC SURVIVOR LOCATION SYSTEM (PROVISIONS)
TI 9900
NOTE SHADED BLOCKS REPRESENT MAJOR SOFTWARE DEVELOPMENT AREAS FOR IBM

5761-048

THERE ARE FOUR REMOTE TERMINAL UNITS, TWO IN THE NOSE ELECTRONICS COMPARTMENT AND TWO IN THE TRANSITION ELECTRONIC COMPARTMENT. THESE DEVICES CONVERT ANALOG SIGNALS AND CONTROL INTERFACES TO DIGITAL SIGNALS COMPATIBLE WITH THE DUAL MIL-STD-1553B DATA BUS. SIGNALS THAT ARE ESSENTIAL TO FLY THE HELICOPTER ARE ROUTED TO TWO REMOTE TERMINALS FOR COMBAT SURVIVABILITY. FUNCTIONAL REDUNDANCY IS ACCOMPLISHED BY ROUTING SOME OF THE COMMUNICATION AND NAVIGATION EQUIPMENT THROUGH SEPARATE UNITS SO THAT A LOSS OF A REMOTE TERMINAL WILL NOT CAUSE LOSS OF ALL COMMUNICATION OR NAVIGATION CAPABILITY.

THE MULTIPURPOSE DISPLAYS, HELMET MOUNTED DISPLAYS, AND THE KEYBOARDS ARE IDENTICAL HARDWARE UNITS THAT ARE WIRED TO PROVIDE COMPLETE BACK UP. THIS PROVIDES A COCKPIT THAT HAS AN ABORT MEAN TIME BETWEEN FAILURE FAR IN EXCESS OF CURRENT COCKPITS.

THERE ARE FOUR MAJOR SOFTWARE DEVELOPMENT PROGRAMS FOR THE HH-60D. THREE PROGRAMS ARE DEVELOPED BY IBM AND THE FOURTH IS DEVELOPED BY TEXAS INSTRUMENTS.

THE OPERATIONAL FLIGHT PROGRAM RESIDES IN EACH OF THE MISSION COMPUTERS. THIS PROGRAM IS ABOUT 70,000 WORDS AND 90 PERCENT OF THE PROGRAM IS IN JOVIAL HIGH ORDER LANGUAGE. THIS PROGRAM INCLUDES THE MAJOR FUNCTIONS LISTED ON THE CHART. SINCE EACH COMPUTER HAS A 128,000 WORD MEMORY THERE IS SIGNIFICANT GROWTH CAPABILITY FOR FUTURE FUNCTIONS.

THE SYSTEM FUNCTION PROCESSOR PROGRAM RESIDES IN EACH OF THE DISPLAY GENERATORS. THIS PROGRAM IS ABOUT 26,000 WORDS IN A 36,000 WORD MEMORY. THE PROGRAM PROVIDES THE MANY DISPLAY FORMATS INHERENT IN THE SYSTEM. SPERRY, THE MANUFACTURER OF THE DISPLAY GENERATOR PROVIDES A 10,000 WORD FIRMWARE PROGRAM THAT INCLUDES THE DISPLAY GENERATOR FUNCTIONS AS WELL AS THE SYMBOLOGY DEFINITION.

THE MAINTENANCE TEST PROGRAM RESIDES IN A MEMORY LOADER/VERIFIER, WHICH IS A PIECE OF GROUND SUPPORT EQUIPMENT. THIS PROGRAM IS CURRENTLY 17,000 WORDS AND IS STORED ON A TAPE CASSETTE OF FAR LARGER MEMORY CAPABILITY. THIS PROGRAM PROVIDES A MAINTENANCE PERSON WITH THE ABILITY TO FAULT DETECT AND ISOLATE TO A REPLACEABLE UNIT WITHOUT USING ADDITIONAL SUPPORT EQUIPMENT.

TEXAS INSTRUMENTS DEVELOPS THE 40,000 WORD MULTIMODE RADAR SOFTWARE PROGRAM. THIS PROGRAM PROVIDES THE SYSTEM PROCESSING AND CONTROL FUNCTIONS FOR TERRAIN FOLLOWING, TERRAIN AVOIDANCE, AND VARIOUS OTHER RADAR OPERATING MODES.

IN ADDITION TO THESE MAJOR SOFTWARE PROGRAMS, IBM IS ALSO DEVELOPING THE SIMULATION AND STIMULATION PROGRAM FOR OUR IBM 370 INTEGRATION LABORATORY COMPUTER AND ALSO A DATA REDUCTION SOFTWARE PROGRAM THAT WILL BE USED OFF SITE DURING DEVELOPMENT TESTING. THE DATA REDUCTION PROGRAM WILL RESIDE IN AN IBM 4300 SERIES COMPUTER.

MANY OF THE OTHER EQUIPMENTS ON THE HH-60D ARE MICROPROCESSORS DESIGNS HAVING THEIR OWN FIRMWARE PROGRAMS. THESE EQUIPMENTS ARE SHOWN ON THE FIGURE.

COCKPIT INTEGRATION

- Two man crew operation design
- 2nd and 3rd NVG lighting compatibility
- Work load reduction features
    - Flight director
    - Alert-by-exception
    - Engine instrument monitoring
    - Integrated sensor and flight data displays
- Display formats and control functions flexibility
    - Software based
    - 525 and 875 line compatibility
    - 3 to 4 or 1 to 1
    - 3 of 5 video inputs used

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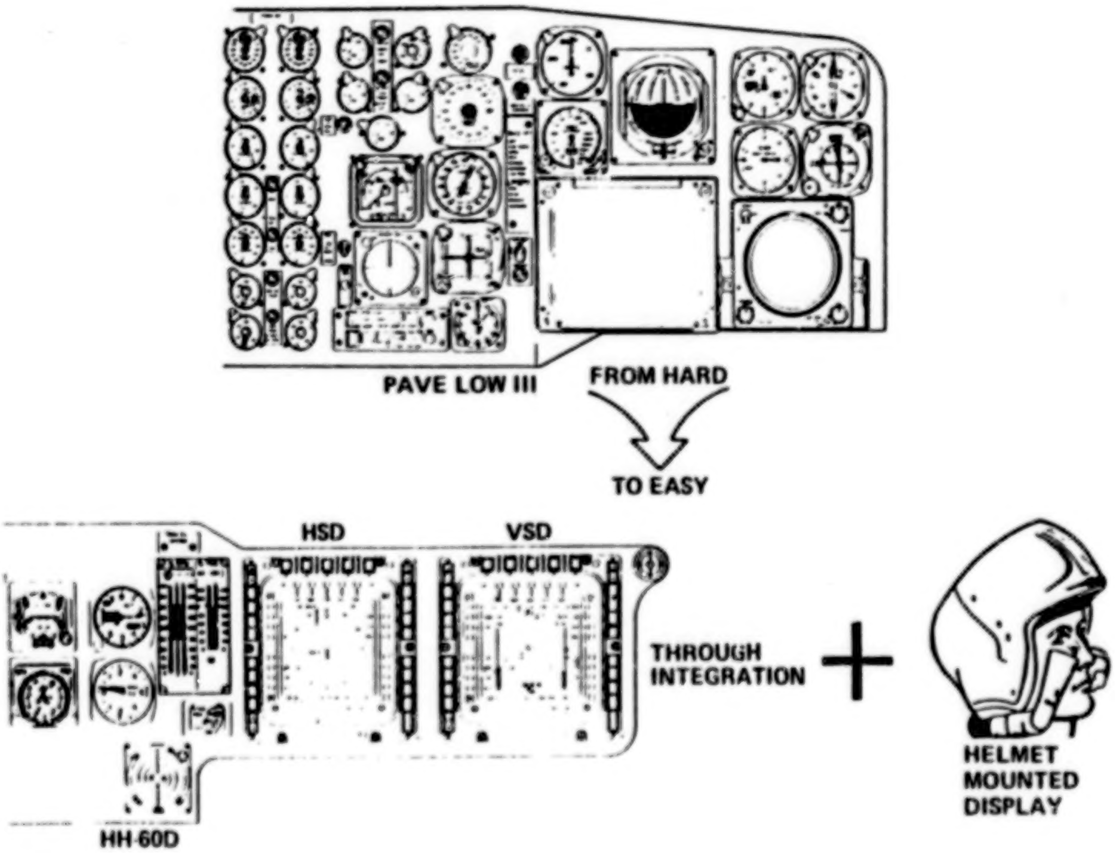
THE COCKPIT IS DESIGNED SO THAT ALL CONTROL FUNCTIONS FOR THE AVIONICS CAN BE OPERATED FROM EITHER PILOT STATION.

THE COCKPIT LIGHTING IS FILTERED INCANDESCENT (AS COMPARED TO ELECTROLUMINESCENT) AND IS GREEN IN COLOR TO AVOID INTERFERING WITH THE RED SENSITIVE NIGHT VISION GOGGLES. THE FILTER DESIGN IS OPTIMIZED TO THE THIRD GENERATION ANVIS GOGGLE, BUT IS ALSO COMPATIBLE TO THE SECOND GENERATION GOGGLE.

THERE IS NO DEDICATED WARNING, CAUTION, ADVISORY PANEL ON THE INSTRUMENT PANEL. INSTEAD THESE ALERTS SHOW UP AS THEY OCCUR, ON THE PILOTS MULTIPURPOSE DISPLAYS. UPON ACKNOWLEDGEMENT BY DEPRESSING A BUTTON, THEY ARE DELETED FROM THE ACTIVE DISPLAY FORMAT AND ADDED TO A COMPUTER LISTING, WHICH CAN BE RECALLED FOR DISPLAY. ENGINE INSTRUMENT READ OUTS ARE CONTINUALLY MONITORED BY THE COMPUTER AND OUT OF TOLERANCE CONDITIONS ARE PROVIDED AS ALERTS. IF THE PILOT WISHES TO VIEW THE ENGINE INSTRUMENTS HE MAY CALL UP AN ENGINE INSTRUMENT DISPLAY FORMAT.

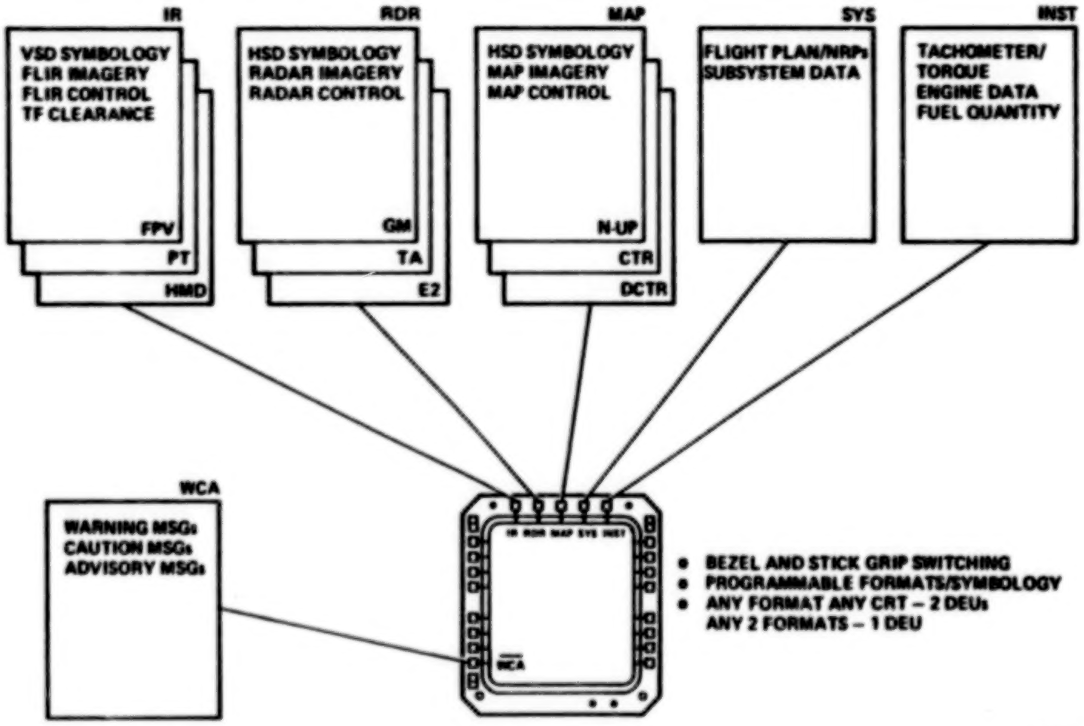
ALL DISPLAY FORMATS AND DISPLAY FORMATS ARE DEFINED BY SOFTWARE AND MAY BE CHANGED DURING DEVELOPMENT WITHOUT HARDWARE IMPACT. DISPLAY HARDWARE CAN ACCOMODATE BOTH 525 AND 875 LINE RASTER EQUIPMENT; HOWEVER, HH-60D SENSORS ARE 875 LINE FOR HIGH FIDELITY SYMBOLOGY AND VIDEO CONSIDERATIONS.



THE PAVE LOW III INSTRUMENT PANEL WAS DESIGNED FOR THE SAME MISSION AND SIMILAR EQUIPMENTS. THERE ARE 77 DISCRETE INDICATORS AND DISPLAYS ON THE PANEL. MANY OF THESE INDICATORS PROVIDE A READ OUT OF ONLY ONE PIECE OF INFORMATION. THE PILOT HAS TO SCAN THESE SEPARATE READ OUTS, ASSIMILATE AND PROCESS THE INFORMATION IN HIS HEAD, AND THEN TAKE APPROPRIATE FLIGHT CONTROL ACTION.

IN THE HH-60D COCKPIT THERE ARE ONLY FOUR MAIN DISPLAYS ON WHICH ALL NEEDED INFORMATION IS DISPLAYED IN A COMPUTER PROCESSED FORMAT EASILY INTERPRETED BY THE PILOT. SENSOR VIDEO IS PROVIDED BEHIND THE COMPUTER SYMBOLOGY IN A NORMALLY EXPECTED MANNER. VERTICAL FLIGHT DATA IS SUPERIMPOSED ON FORWARD LOOKING INFRARED VIDEO. HORIZONTAL FLIGHT DATA IS SUPERIMPOSED ON A PLAN VIEW MAP OR RADAR PICTURE. BACK UP INSTRUMENTS ARE HARD WIRED TO AIRCRAFT SENSORS AND RADIO AIDS AND ARE LOCATED IN THE CENTER OF THE INSTRUMENT PANEL, JUST-IN-CASE.

DISPLAY FORMATS/SYSTEM MODE CONTROL


IR
VSD SYMBOLOGY
FLIR IMAGERY
FLIR CONTROL
TF CLEARANCE
FPV
PT
HMD
RDR
HSD SYMBOLOGY
RADAR IMAGERY
RADAR CONTROL
GM
TA
E2
MAP
HSD SYMBOLOGY
MAP IMAGERY
MAP CONTROL
N-UP
CTR
DCTR
SYS
FLIGHT PLAN/NRPs
SUBSYSTEM DATA
INST
TACHOMETER/
TORQUE
ENGINE DATA
FUEL QUANTITY
WCA
WARNING MSGs
CAUTION MSGs
ADVISORY MSGs
IR RDR MAP SYS INST
WCA

- BEZEL AND STICK GRIP SWITCHING
- PROGRAMMABLE FORMATS/SYMBOLOGY
- ANY FORMAT ANY CRT – 2 DEUs
  ANY 2 FORMATS – 1 DEU

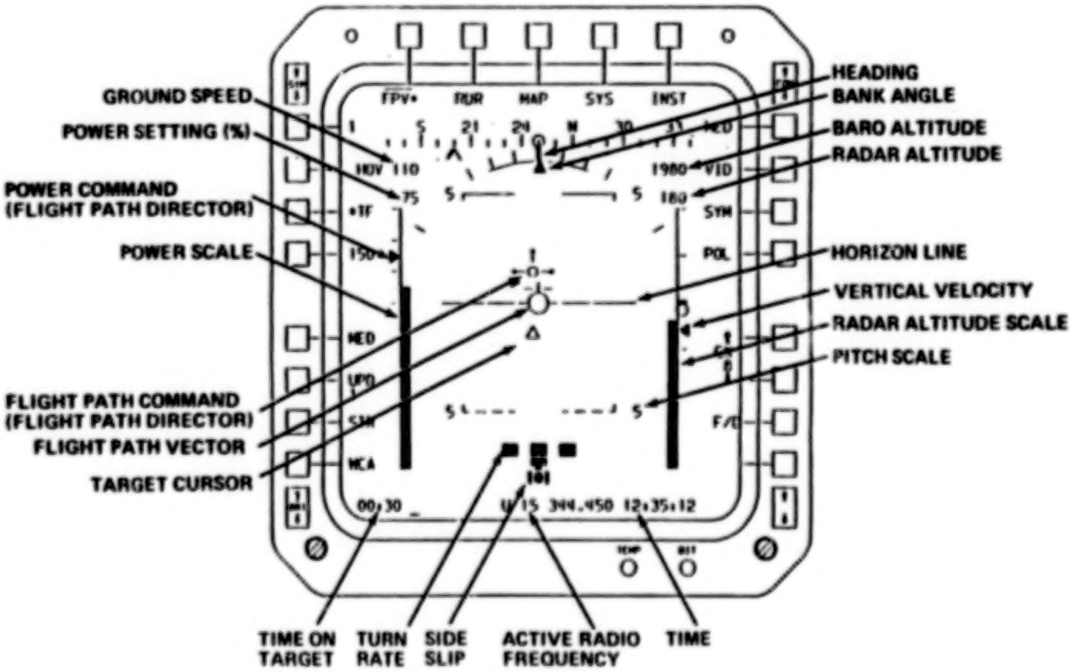
5867-701A

EACH MULTIPURPOSE DISPLAY HAS FIVE KEY SWITCHES ON THE TOP AND EIGHT KEY SWITCHES ON EACH SIDE. THE FIVE TOP SWITCHES SELECT THE MAJOR MODE OF THE DISPLAY WHILE THE SIDE SWITCHES ARE FOR SUBMODES AND CONTROL FUNCTIONS APPROPRIATE FOR THE SENSOR ASSOCIATED WITH THE MAJOR MODES. THE CONTROL FUNCTIONS ARE RESIDENT IN SOFTWARE AND LABELS FOR THE SIDE SWITCHES CHANGE AS MAJOR MODES ARE SELECTED.

THE LEFT TOP KEY SWITCH SELECTS A VERTICAL SITUATION DISPLAY SYMBOL FORMAT SUPERIMPOSED ON A FORWARD LOOKING INFRARED VIDEO RASTER. THE FIRST DEPRESSION OF THIS SWITCH CONFIGURES THE FLIR TURRET TO BE STABILIZED ALONG THE AIRCRAFT VELOCITY VECTOR. A SECOND DEPRESSION ENABLES THE OPERATOR TO POINT THE FLIR USING THE CENTER CONSOLE MOUNTED SLEW CONTROL. THE THIRD DEPRESSION SLEWS THE TURRET TO THE HELMET MOUNTED DISPLAY. FURTHER DEPRESSIONS CAUSE THE SEQUENCE TO REOCCUR IN THE ORDER DESCRIBED.

THE SECOND FROM THE LEFT KEY SWITCH SELECTS A HORIZONTAL DISPLAY SYMBOL FORMAT SUPERIMPOSED ON A RADAR GROUND MAP VIDEO RASTER. SUBSEQUENT DEPRESSIONS CHANGE THE VIDEO TO A TERRAIN AVOIDANCE AND ELEVATION VERSUS RANGE DISPLAY.

VSD FLIGHT PATH VECTOR MODE



FPV•
TUR
MAP
SYS
INST
HOV
•TF
MED
UPD
SYN
MCA
VID
SYM
POL
F/D
110
75
150
1980
180
00:30
U 15 344.450 12:35:12
GROUND SPEED
POWER SETTING (%)
POWER COMMAND (FLIGHT PATH DIRECTOR)
POWER SCALE
FLIGHT PATH COMMAND (FLIGHT PATH DIRECTOR)
FLIGHT PATH VECTOR
TARGET CURSOR
HEADING
BANK ANGLE
BARO ALTITUDE
RADAR ALTITUDE
HORIZON LINE
VERTICAL VELOCITY
RADAR ALTITUDE SCALE
PITCH SCALE
TIME ON TARGET
TURN RATE
SIDE SLIP
ACTIVE RADIO FREQUENCY
TIME

THE THIRD TOP KEY SWITCH SELECTS THE HORIZONTAL DISPLAY SYMBOLOGY AND A NORTH-UP MAP READER VIDEO RASTER. SUBSEQUENT DEPRESSIONS ALLOW SELECTION OF A HELICOPTER POSITION CENTERED FORMAT, AND A HELICOPTER POSITIONED DECENTERED FORMAT. THE LAST TWO FORMATS ARE ALIGNED TO AN AIRCRAFT TRACK UP ORIENTATION.

THE SYSTEM KEY SWITCH PROVIDES DISPLAY AND ACCESS TO THE VARIOUS TABULAR DATA IN THE COMPUTER. EXAMPLES INCLUDE THE SYSTEM EQUIPMENT STATUS TABLE, NAVIGATION REFERENCE POINTS, AND THE FLIGHT PLANNING AND FUEL AND POWER MANGEMENT TABLES.

THE RIGHT KEY SWITCH PROVIDES IMMEDIATE DISPLAY OF AIRCRAFT ENGINE AND ROTOR DATA IN AN ANALOG FORMAT SIMILAR TO THE UH-60A HARDWARE DISPLAY INSTRUMENTS. ALSO DISPLAYED ARE THE FUEL QUANTITY STATUS OF THE FIVE FUEL TANKS ALONG WITH TOTAL FUEL REMAINING.

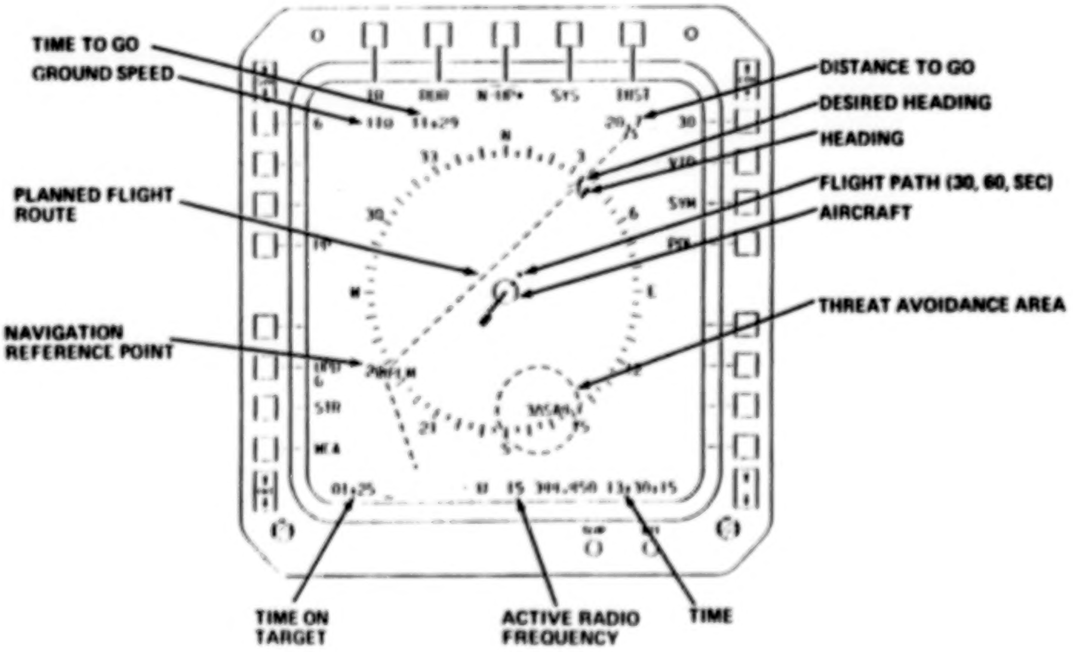
A COMPUTER LIST OF ACTIVE CAUTION, WARNING, AND ADVISORY ALERTS ARE IMMEDIATELY AVAILABLE BY PRESSING THE LOWER LEFT SIDE KEY SWITCH.

TYPICAL SYMBOLOGY FOR THE VERTICAL SITUATION DISPLAY INCLUDES THE DATA SHOWN. A SYMBOL KEY SWITCH ON THE RIGHT SIDE OF THE DISPLAY ALLOWS AN OPERATOR TO SELECT TWO LEVELS OF SYMBOL DECLUTTER.

A FLIGHT PATH VECTOR COMMAND SYMBOL LOCATED IN THE CENTER OF THE DISPLAY AREA PROVIDES GUIDANCE TO THE PILOT BASED UPON PROCESSED SENSOR SIGNALS. THIS FLIGHT PATH VECTOR DIRECTOR HELPS THE PILOT MAINTAIN DESIRED TERRAIN FOLLOWING CLEARANCE AND PLANNED NAVIGATION COURSES AS WELL AS MAINTAINING GLIDESLOPE, LOCALIZER, AND TACAN APPROACHES UPON SELECTION.

A UNIQUE POWER SCALE ON THE LEFT SIDE OF THE DISPLAY INDICATES AMOUNT OF POWER BEING USED TO SUSTAIN THE CURRENT FLIGHT STATE. A SMALL INDICATOR ON THE LEFT OF THE TAPE IS DRIVEN BY THE FLIGHT PATH DIRECTOR AND INDICATES THE AMOUNT OF POWER THAT IS REQUIRED UPON SATISFYING THE COMMAND. WHEN THE TERRAIN FOLLOWING MODE IS BEING USED, THIS SYMBOL WILL LET THE PILOT KNOW WHEN A MOUNTAIN ALONG THE FLIGHT PATH REQUIRES PULLING MORE COLLECTIVE THAN AVAILABLE. THE PILOT CAN THEN ELECT TO SLOW DOWN FOR MORE CLIMB CAPABILITY OR GO AROUND THE MOUNTAIN USING HIS TERRAIN AVOIDANCE FORMAT ON HIS OTHER DISPLAY.

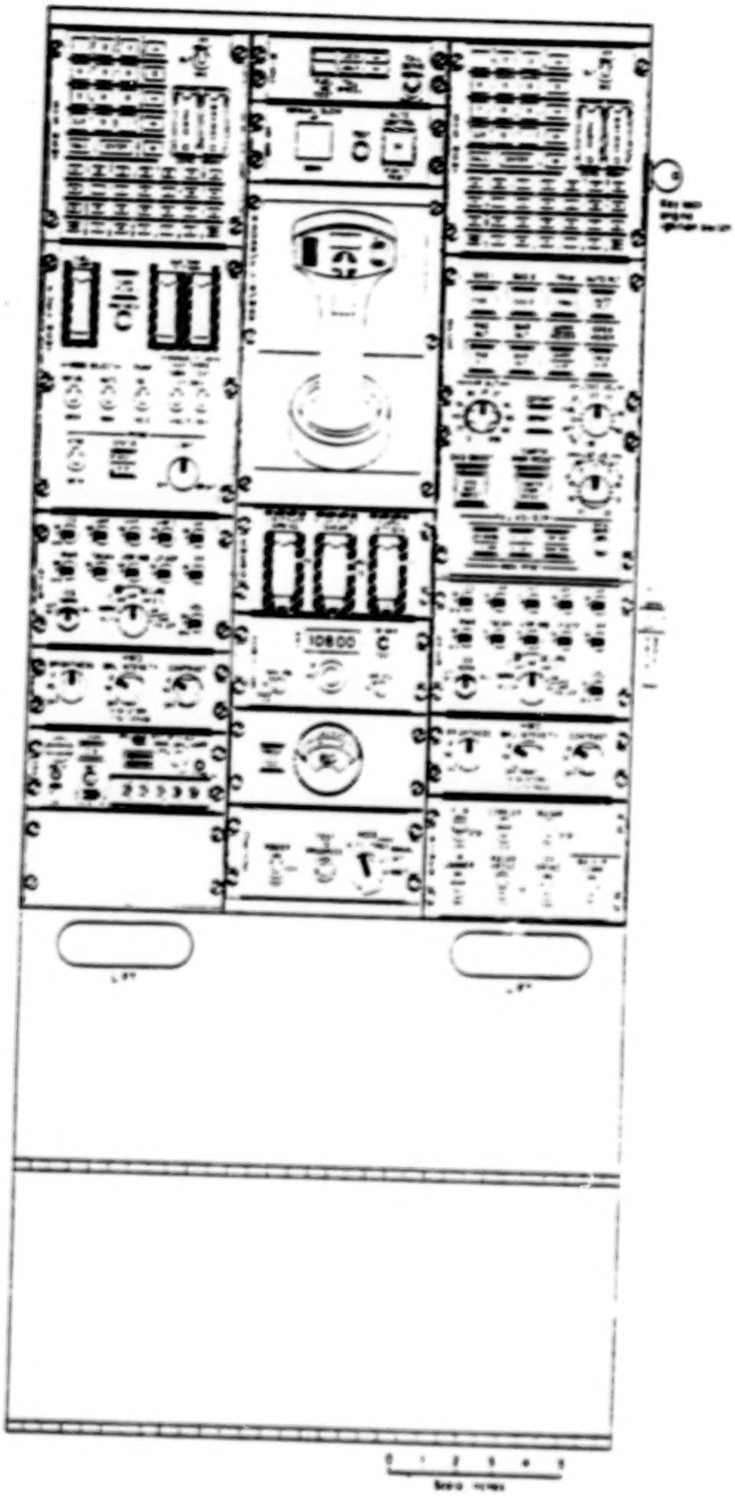
HSD NORTH UP MODE


TIME TO GO
GROUND SPEED
PLANNED FLIGHT ROUTE
NAVIGATION REFERENCE POINT
DISTANCE TO GO
DESIRED HEADING
HEADING
FLIGHT PATH (30, 60, SEC)
AIRCRAFT
THREAT AVOIDANCE AREA
TIME ON TARGET
ACTIVE RADIO FREQUENCY
TIME

TYPICAL HORIZONTAL SITUATION DISPLAY SYMBOLOGY IS SHOWN SUPERIMPOSED ON THE VIDEO MAP RASTER.

NAVIGATION REFERENCE POINTS WITH THE PLANNED COURSE AND THREAT AVOIDANCE AREAS ARE ALSO DISPLAYED.

ORIGINAL PAGE IS
OF POOR QUALITY


10800
0 1 2 3 4 5

CENTER CONSOLE

THE CENTER CONSOLE PROVIDES CONVENIENT CONTROLS FOR BOTH PILOTS. A KEYBOARD ALLOWS EITHER PILOT TO ENTER DATA INTO THE SYSTEM. A MANUAL SLEW CONTROL STICK CAN BE USED TO MOVE A DISPLAY CURSOR, POINT THE FLIR TURRET, OR ALTERNATELY SLEW THE DISPLAYED MAP VIDEO TO A NEW AREA.

INTERCOMMUNICATION PANELS HAVE IN/OUT SELECT KNOBS FOR THE VARIOUS RADIOS WITH INTEGRAL ROTATING VOLUME CONTROLS. A ROTARY TRANSMISSION CONTROL ALLOWS EACH STATION IN THE HELICOPTER TO SELECT THE INDIVIDUAL RADIO FOR TRANSMISSION.

OTHER PANELS ARE PROVIDED AS SHOWN.

FUNDAMENTAL ISSUES

MISSION NEED	PRIMARY DESIGN AREAS
1. EXPLOIT NIGHT/ADVERSE WEATHER CONDITIONS	RADAR, FLIR, DISPLAYS, NVGs, LIGHTING
2. LOW LEVEL TF/TA (100 FT, 100-125 KTS)	RADAR, FLIR, DISPLAYS, TF PROCESSING, NAVIGATION
3. LOW WORKLOAD (2 MAN OPERATION)	COCKPIT ARRANGEMENT, DISPLAY FORMATS, MODING, SWITCHOLOGY, AURAL CUES, LIGHTING
4. HIGH SURVIVABILITY ($MCSP_{AVIONICS} = 0.94$ MATURE)	REDUNDANCY, BACK UP MODES, EQUIPMENT PLACEMENT, EQUIPMENT RELIABILITY
5. ACCURATE SURVIVOR/LANDING ZONE LOCATION, RAPID HOVER (OR LAND) AND DEPARTURE	UHF/VHF ADF PROCESSING, ELECTRONIC SURVIVOR LOCATION EQUIPMENT (ESLE), COMPUTER GENERATED SEARCH PATTERNS, FLIGHT DIRECTOR
6. HIGH OPERATIONAL READINESS	ON BOARD STATUS MONITORING, INTEGRATED DIAGNOSTICS

THE FUNDAMENTAL ISSUES POSED BY THE REQUIREMENTS REQUIRED INNOVATIVE DESIGN PRIMARILY IN THE COCKPIT AND THE WORK LOAD REDUCTION SOFTWARE FUNCTIONS. THE KEY TO RESOLVING THESE ISSUES IS IN THE UNIQUE SENSOR AND FLIGHT INFORMATION PROCESSING INTEGRATION DESCRIBED DURING THIS SHORT BRIEFING. THESE DESIGNS WILL BE THOROUGHLY TESTED IN IBM'S INTEGRATION LABORATORIES DURING THE FORTHCOMING YEAR. DURING THIS TIME HARDWARE AND SOFTWARE SYSTEMS INTEGRATION WILL CULMINATE IN A FULL MISSION SIMULATION DEMONSTRATION PRIOR TO FLIGHT TEST. IF SOME DISPLAY FORMATS OR SYMBOLOGY DO NOT ACCOMPLISH THEIR PURPOSE, THEY WILL BE CHANGED THROUGH THE FLEXIBILITY THAT ONLY SOFTWARE PROVIDES.

ACTUAL DEVELOPMENT FLIGHT TESTING WILL BE ACCOMPLISHED BY THE AIR FORCE DURING 1985 AT EDWARDS AFB IN CALIFORNIA.

FUTURE TRENDS

- DATA ENTRY DEVICE
- GPS
- COLOR DISPLAY
- INTEGRATED FD/AFCS (AUTO NAV, AUTO TF)
- VOICE ACTUATED CONTROL
- VOICE WARNING
- NVG/HMD HELMET
- HMD/POD MOUNTED GUN TURRET
- AIR-AIR MISSILE
- INTEGRATED QUICK REACTION DEFENSIVE SUBSYSTEM
- ELECTRONIC SURVIVOR LOCATION EQUIPMENT
- DATA EXTRACTION

(REFERENCE 6015-3A)

ALTHOUGH WE ARE CURRENTLY UNDER CONTRACT FOR A WELL DEFINED AVIONICS CONFIGURATION THAT IS PRACTICAL AND AFFORDABLE AT THIS TIME, THERE ARE MANY OTHER FEATURES THAT BECOME AVAILABLE IN THE FUTURE. SOME OF THE FUTURE AVIONIC CHANGES BEING CONSIDERED AS CHANGES ARE SHOWN. SOME OF THESE ITEMS ARE CURRENTLY BEING EVALUATED IN IBM LABORATORY FACILITIES FOR APPLICATION TO DIFFERENT FUTURE SYSTEMS SUCH AS JVX, LHX, AND COMBAT TALON.

TIME ALLOCATED FOR THE HH-60D BRIEF PRECLUDES THE SHOWING OF A VIDEO TAPE DESCRIBING THE USE OF THE COCKPIT DISPLAY AND CONTROL FUNCTIONS DURING A TYPICAL COMBAT SEARCH AND RESCUE MISSION. THIS TAPE IS VERY INFORMATIVE AND IS AVAILABLE FOR VIEWING UPON REQUEST.

N85 14818 D12

AVIONICS/CREW STATION INTEGRATION

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SUMMARY

The U.S. Navy has been encouraging advanced development concepts aimed at increasing the aircraft instrumentation performance for multi-platform applications of 1990's weapons systems. The three areas covered by the Navy's research and development effort are System Integration, Technology, and Human Factors. The objectives of these three areas are as follows:

- The System Integration objectives are to produce a system architecture easily adaptable to many platforms.
- Technology objectives are to determine the state of the art for displays, electronics, and controls.
- The Human Factors objectives are to determine the proper human-machine interfaces so that the ultimate crew station will be capable of providing the pilot with the proper display and controls performance to satisfy the diverse requirements of a fighter, attack, ASW, fixed-wing, rotary-wing, and V/STOL platforms in both a one-man crew or two-man crew matrix.

All data/control interface among units of this crew station system and other platform subsystems will be via digital data buses and video multiplex buses. No individual discrete signal, data, or control lines will be needed. This paper discusses the six interfaces necessary to ensure the optimum development of this crew station, the predicted platform mission improvements, and the requisite life-cycle cost considerations. This concept will serve as a basis for planning the integration of the necessary hardware and software features in current and future weapons systems.

BACKGROUND

The requirement for a significantly improved approach to aircraft cockpit instrumentation and controls arises from the basic need for improved military effectiveness against all existing and planned piloted weapon systems. Increased effectiveness is needed to counter the threat posed by potentially hostile forces while accomplishing this goal within the bounds set by present constraints on essential resources.

U.S. Naval Air Forces will continue to be faced with a constantly escalating threat to their ability to maintain air superiority and sea control on a global basis, 24 hours a day and under instrument meteorological conditions - instrument flight rules (IMC-IFR).

As weapon system performance parities among competing force structures are achieved, as the life-cycle cost of operational equipment continues to increase, and as the sophistication of both the equipment and its required Naval air mission continues to grow, the greater becomes the importance of the human-machine interface in exploiting the maximum capabilities of the piloted aircraft.

Now, a need exists for a totally new approach to cockpit instrumentation and controls. In response to this need, the Naval Air Systems Command initiated development efforts on the Advanced Integrated Display System (AIDS) as the most feasible approach to meeting the demands of the 1990's weapons systems.

The AIDS will provide weapons systems improvements in the following three general areas of effectiveness, adaptability and supportability.

Effectiveness

- The tactical posture of the pilot will be improved in two ways: (1) there will be more time to assess a situation and make a decision through reduced visual scan time as compared to discrete instrumentation, and (2) there will be improved contact with the world "outside the cockpit" under all-weather conditions with tactical problems overlaid on automated situation displays.
- Aircraft availability will be improved through functional redundancy in display systems and through ranking of failure modes to distinguish between critical and non-critical situations.

Adaptability

- The modular nature of AIDS provides a building block capability that allows application of the complete system or its components in new or existing aircraft.
- While the most pressing need is seen as the single-place combat platform, both the technology and components are suited to the multi-manned aircraft as well.
- AIDS will employ technology that is similar to or compatible with sensor system developments likely to be in use over an extended period of time.

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Supportability

- AIDS will reduce the number of individual types of these equipments in the Naval inventory.
- AIDS will reduce the number of individual skills now required to maintain aircraft instrument/display systems.
- AIDS will reduce training time requirements in each area for both pilots and maintenance personnel.
- AIDS will reduce downtime through maximum use of solid-state components and integrated circuitry that is compatible with built-in test (BIT) and automatic test equipment (ATE).

WEAPON SYSTEM COSTS

A major factor in the acquisition of any modern military system, particularly a weapons system, is the planning, control, and minimization of system life-cycle costs. These costs accrue from initial development and acquisition of a weapons system, and continue through the operational and support phases of the system. Costs of system operations must include training of operational and maintenance personnel, operational software development, and the development of adequate operational, intermediate, and depot level maintenance documentation. The elements of Integrated Logistics Support (ILS) come into play to ensure optimum support of the operational weapons systems throughout their life cycle.

With these points in mind, let us look at the various elements to be considered in the life-cycle cost planning of a crew station.

SYSTEMS DEVELOPMENT COSTS

The systems of the future must be capable of being assembled, much like the "Tinker Toys" we played with as a child. The hardware, software and interfaces must be so designed that they can be assembled, integrated and tested by medium-skilled personnel in a reasonably short (therefore less costly) period of time. The hardware and software must be so simple and so transparent to the technology that the interfacing of these hardware and software modules present only a minimal task.

Hardware Development

Programs such as the U.S. Air Force Digital Avionics Information Systems (DAIS) and the U.S. Navy Advanced Integrated Display System (AIDS) have developed hardware that can be used as prototypes for interchangeable modules in future aircraft and retrofit of existing weapons systems. The components of these systems are shown in Figure 1. Both programs are proving that modular concepts in hardware development are possible. Again, the technical problems are surmountable while the financial roadblocks are proving not to be. These modules, like any new model, have higher initial costs. The life-cycle costs, where the real savings will be, are not being taken into account because of today's fiscal limitations.

Software Development

Today, for a data processing system, 80 per cent of the total cost is for software. This software percentage is expected to increase by 1985 so that 90 per cent of the systems costs will be for the software.

Military Higher-Order Languages (HOL's) such as ADA (DoD), JOVIAL (USAF), and CMS-2 (USN), have been developed for the large quantity, high-speed computations associated with sensor signal processing. However, not enough attention is being paid to real-time interactive graphics requirements needed for today's system, much less the larger demands predicted for the future for large-scale computer graphics in real time.

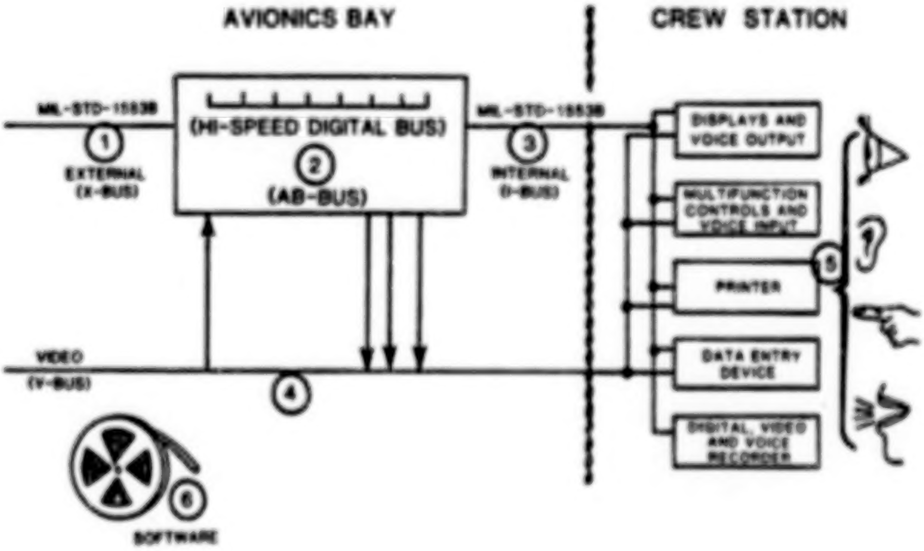

Figure 1. Displays and Control Interfaces

The languages must allow a non-programmer of the future to interact with these new systems so that medium-trained personnel can develop and evaluate new and innovative concepts in system operability. This should allow for more acceptability due to the adaptation, more quickly that realizable today, to the changing mission requirements and changing tactics.

Interface Development

The interface area is receiving more and more attention through the expanding use of MIL-STD-1553B. This expanding use is experiencing growing pains, as any new concepts do, but the development bugs are being ironed out. However, there are three problem areas that deserve increased attention.

First, the military with their 1553B, and the commercial airlines with the ARINC 429, are developing incompatible systems. Therefore, cost savings derived from large-quantity productions are going to be lost to the military since their share of the market is diminishing.

Second, there is the requirement for transmission of information at a higher rate than one megabit (1553B limit). This has been recognized and an analysis is being conducted of today's and future requirements for high-speed digital transmissions.

Third, there is the requirement, unique to the crew station community, for the transmission of video information. The AIDS has developed a video bus, very similar to a cable TV system, that will facilitate the initial development and future modification of integrated multi-function displays. The video bus utilizes standard composite TV for two important reasons; it is readily available and compatible equipment is very reasonable in cost. This is fine for 525-line monochrome systems. We are attempting to define what should be done for a color system and higher line rates such as 875 and 1024. The NTSC Color standard is not acceptable for small symbology. An R-G-B type of interface is some improvement, but requires too much bandwidth. This area requires much more effort than it is presently receiving.

PRODUCTION COSTS

The production of these systems must be kept in mind during the development phase. The electronics technology has made such tremendous strides with LSI and VLSI that other technologies have been left in the dust. Recent advancements in optics, such as fiber optics and diffraction optics, may make this expensive technology more reasonable in the future. But other areas, such as flat panels, must be producible on a large scale with automation maximized.

OPERATIONAL COSTS

Operational costs are directly relatable to operational complexity. Therefore, the primary goals in effective weapons systems operation should be to make the human-machine interface so easy to operate that operator training and proficiency update requirements would become almost negligible. This can be achieved by making the machine as adaptive as possible to stimulate the natural senses of the human. Long-term cost savings could be attained, not only in training and proficiency (in both simulator and flight time) costs, but though reducing loss of equipment due to "operator error."

If we think of the human-machine interface simply as communication between the operator and the machine, then perhaps an analogy can be drawn to communication between one person and another person.

The person-to-person intercommuncations uses visual (alphanumeric, graphic and pictorial), auditory (speech) and motion. Therefore, if we are to make the person-to-machine communications as effective as person-to-person communications, we must have:

1. Printed information
2. Graphical information
3. Pictorial information
4. Two-way verbal communications
5. Motion and position sensing.

Assuming again that the closer we approach person-to-person communication, the better, then, the graphical and pictorial information must be, in both 2D and 3D and with all information in full color. The system must be reactive to the individual operator and must be tailored to his specific needs, both normal and abnormal. The Mark I individuals, with whom we must operate, are all different. To expect all individuals to fit one mold is nice in theory, but impossible in reality.

The systems of the future will have the capability for programmed "level-of-acceptable performance" defined for every important task of every mission mode. The system can evaluate the operator's performance and, if it falls below this level, it will take over more and more of the functions until the operator's performance is back to an acceptable level. As the performance exceeds this level by a specified amount, the system offers to give back to the operator some of the functions, if he wants them. This level of performance may be raised, from some specified lower limit, by the operator as he undergoes his training. This would allow the operator to decide how many functions and in what priority he wishes to transfer the the system. Of course, this delta can be modified up or down (to the lower limit) throughout the operator's experience. The term "operator" is used here because performance is applicable not only to the pilot, but could be implemented for navigators, sensor station operators, tactical officers, etc.

Also during training, the operator can have some freedom in selecting the type of information that is presented to him during the various mission modes, as well as the response of the system to his commands. This will allow the "picture person" and the "word person" to tailor the system to his individualized tastes, thereby improving acceptability, improving operability, and reducing life-cycle costs.

This natural system can almost certainly include voice communication, meaning voice recognition (phrases first, then continuous speech) and voice synthesis (completely synthetic or reconstructed digitally stored voice). The Helmet Mounted Display (HMD) will be capable of taking over an increasingly larger and larger amount of the information presentation until it is the only display in the crew station. The instrument panel will be black and a synthetic instrument panel will be generated on the HMD when the operator looks in that direction. Eventually, that requirement will be deleted and the operator will keep his head and eyes out of the crew station at all times. The HMD evolution will be monocular, biocular and then binocular, starting in monochrome and eventually evolving to color because, as stated earlier, seeing images in color and 3D are the natural way of viewing the real world.

Multifunction controls are becoming increasingly accepted. They have the capability of being introduced into the consoles initially and finally right into the armrests of the seat. Feedback systems to the HMD will tell the operator which switch his finger is on before he presses the button so that he will not have to bring his eyes back into the crew station to view the multifunction controls. The multifunction controls and voice recognition will probably become so intertwined that each will be a primary mode of input for some individuals while the other will be back-up.

All of these increases in capability will be reflected in reduced operational costs, due mainly to training time reductions and decreased loss of equipment due to "operator error".

SUPPORT COSTS

System life-cycle costs can be further reduced and controlled through effective planning of the Integrated Logistics Support (ILS) and system reliability and maintainability (R&M).

The necessary steps to solving maintenance problems include the following:

1. Recognizing a malfunction
2. Isolating the malfunction
3. Correcting the malfunction
4. Verifying the correction
5. Documenting the maintenance action

The AIDS Program includes the following equipment at the crew station:

AIDS Equipment	Common Name
Displays	CRT
Multifunction Controls	Keyboard
Briefing Information Entry Device	Tape Drive
Maintenance Recorder	Printer

If one looks at the list on the right, it is not hard to call the crew station a computer terminal station. Thus, the crew station can now become the maintenance shop for all the hardware in that particular aircraft. Available are most of the necessary tools (BIT, diagnostics, instructions, etc.) to be used by the maintenance person to perform on-line tests to effect all of the remedial maintenance required, thereby reducing system down time and, consequently, costs.

Imagine the following scenario:

Our maintenance section is requested to ensure that 10 to 15 F-25's, that have just landed, will be ready for this afternoon's mission.

Joe Average and his counterparts are assigned to report upon the status of each aircraft. Joe goes to BUNO 17369 and, without need of electrical power, reads the printout from the crew station printer to his supervisor over a portable communication link. (The printer had developed two copies of the report upon landing, listing all malfunctions, when they occurred, if they are intermittent, and what was the last status of the malfunctioning equipment. The pilot tore off one copy to be submitted during his debriefing, leaving the other copy in the crew station for the maintenance personnel.) The maintenance supervisor informs Joe that this aircraft is needed and that Joe should be able to correct these malfunctions in time for this afternoon's flight.

Beside each malfunction on the printout is a number that coincides with the number of the digital cassette containing the diagnostic software for that problem. Joe selects the cassette from the container he carries with him. Inserting the cassette into the Tape Drive will run a diagnostic program and, on the CRT, display the corrective action required. Questions can be asked by Joe if he is not sure of what steps he must take. In reply, he might receive the following instructions:

1. Go to Avionics Bay 1 (front-left)

2. Third shelf from top

3. Replace 14th module from the right (MODULE 743)

4. Tools needed

- Cross-point screwdriver
- Cutting pliers
- Needle-nose pliers

After Joe is convinced that he understands the operations, he requests a chit for Module 743. The printer then prints the chit for him as well as the list of tools required.

After Joe has submitted the chit and received Module 743 and the tools from supply, he goes to Avionics Bay 1 in the aircraft and plugs his helmet connection into shelf number three. Information is presented on the visor of his helmet and over his earphones that he is indeed in Avionics Bay 1 and is at the third shelf from the top. (Or, if he is at the wrong location, he will be informed that he has made a mistake and is in, for example, Bay 5, the second shelf.) The removal of the 14th module from the right is also verified (or not, if he is wrong). The replacement of this module initiates the rerunning of the diagnostic program and tells him that he has indeed corrected the malfunction. He requests a printout of the maintenance action and receives a printout of the corrective actions taken, as well as the time taken to correct the malfunction. This printout will be turned in to his maintenance supervisor for inclusion in the next maintenance report.

Joe had to do minimal reading. He had a chance to assure himself of the steps he was going to take, before he started, by requesting information from an impersonal machine. He was reassured along the way that he was correct, step by step. He was congratulated in the end for a job well done and, most importantly, he personally did not have to fill out one form, yet all the required forms were filled out correctly. This improved maintenance action will result in improved logistics.

Had this been a LAMPS helicopter or a VSTOL aircraft operating from a destroyer, the cockpit may have been the only space available for any maintenance investigation aboard the ship.

INTERFACES

Figure 1 portrays the six interfaces that must be controlled for effective crew station design.

These interfaces are as follows:

1. External Bus (X-Bus)

The X-Bus proposed for transmission of digital data from aircraft sensors and computers to the avionics bay display electronics would be a serial digital bus that would conform to MIL-STD-1553B. A pair of buses would be required to provide redundancy.

2. Avionics Bay Bus (AB-Bus)

The AB-Bus proposed for transfer of digital data between various user elements installed in the aircraft avionics bay such as Digital Processor, Mass Memory, Raster Symbol Generator, X-Bus Interface and I-Bus Interface would require a high-speed, 16-bit, parallel, digital bus.

The basic purpose of the AB-Bus is to transfer data from one user element to another in a distributed processor system. The AB-Bus has a number of input and output interrupts corresponding to the number of elements connected to the bus. Each element on the bus, when selected, has a 512-k word address capability and communicates with the bus controller over a pair of input and output interrupts. The input interrupts are used for user element communications to the AB-Bus Controller and output interrupts are used for AB-Bus controller to the user element.

3. Internal Bus (I-Bus)

The I-Bus proposed for transmission of digital data from the aircraft avionics bay to the crew station displays and controls would also be a serial digital bus that would conform to the MIL-STD-1553B. As for the X-Bus, the I-Bus will consist of a pair of buses. However, both I-buses could be in use full time. Then the unlikely failure of one bus would require the reconfiguration of the remaining bus to operate on a degraded mode. The system would be designed so that the bus controller would monitor the bus and, when it detects a failure, would automatically institute a bus reconfiguration according to a set of predefined priorities.

4. Video Bus (V-Bus)

The V-Bus, through the use of a video multiplexing system, will distribute several video and sync signals among multiple display terminals. This type of video signal distribution is similar to that used in commercial cable television. The V-Bus permits signals from multiple sources to be carried on one bus for display at selected moments on any number of crew station displays. The ability to transmit multiple video signals enables the sources of the signal as well as display units to be changed or new ones to be added without requiring major rewiring of the aircraft. The primary requirement of the signal sources and displays is that they are compatible to the characteristics to be defined for both the video bus and data bus.

Each display unit contains a Digitally Tuned Receiver (DTR) that is connected to a data bus. Commands can be sent through the DTR over the data bus to tune a display to receive video from any of the external sources, generally sensors, TV missiles, or the Raster Symbol Generator (RSG) located in the avionics bay of the aircraft. The RSG, through a DTR, can be commanded to receive the sensor data and combine it with symbology and retransmit the combined video signal to a crew station display unit.

To ensure fail-safe conditions, two video buses and two data buses would be installed with the bus controller monitoring bus operation. Should the controller detect failure of one bus, the second bus would be reconfigured to operate in a degraded mode to permit transmission of required signals. A priority system would have to be developed as a function of critical parameters to be defined to enable successful completion of the aircraft mission.

5. Operator/Machine Interface

The operator/machine interface is receiving more and more attention. The use of multifunction displays and controls hopefully will preclude the following results of a study of five years of Naval aircraft accidents:

- Incorrect use of emergency procedures: 33 aircraft destroyed, 13 aircraft damaged, 19 fatalities.
- Incorrect use of checklist: 5 aircraft destroyed, 18 aircraft damaged.
- Lack of stabilator position indicator (peculiar to F-4): 8 aircraft destroyed, 6 fatalities.
- Lack of subsystem malfunction advisory information: 42 aircraft destroyed, 65 aircraft damaged, 75 fatalities.
- Lack of midair warning system: 8 aircraft destroyed, 7 aircraft damaged, 10 fatalities.
- Lack of VN envelope information to pilot: 42 aircraft destroyed, 8 aircraft damaged, 27 fatalities.
- Lack of VQ envelope information to pilot: 18 aircraft destroyed, 5 aircraft damaged, 20 fatalities.
- Lack of altitude warning system: 34 aircraft destroyed, 6 aircraft damaged, 59 fatalities.
- Inadequate precision approach information: 15 aircraft destroyed, 46 aircraft damaged, 4 fatalities.
- Inadequate CVA precision departure information (reverse ACLS): 16 aircraft destroyed, 21 fatalities.
- Lack of accurate rate-of-sink indications: 6 aircraft destroyed, 2 aircraft damaged, 7 fatalities.

What is required is the capability to demonstrate a coherent solution to the problem of proliferation and nonstandardization of aircraft displays and controls. To achieve this purpose, efforts are being directed toward development of crew stations based upon digital computers, utilizing a high-order programming language. The flexibility of such digital computers and their accompanying digitally driven displays has created radically new capabilities to be utilized in the design of crew stations. The total dependence on the use of dedicated, round-dial and taped instruments is at an end. The digital computer allows the implementation of multiprogrammable electro-optical displays, such as those used in the F-18; it also allows for the use of programmable controls such as those used in the F-16 stores management panel. The electro-optical, multifunction displays and controls offer significant advantages over their dedicated counterparts in that one electro-optical display, through the use of various display format changes, can encompass the information presented on many dedicated displays. Early emphasis in both Air Force and the Navy has been on transferring formats from electromechanical instruments to cathode ray tubes (CRT's). The product of these early efforts has come to fruition and is extensively employed in the F-18 aircraft and, to a more limited extent, in the F-16 aircraft. There is reasonable concern that the pilot may have trouble in fully utilizing the tremendous amount of alphanumeric information currently being presented to him on the electro-optical devices. We may have reached a state where the information processing of the human is a limiting factor in the use of more alphanumeric information. The answer to this concern and the objective of this effort is the simulation and evaluation of new formats that are based upon vectorgraphic or pictorial information as opposed to the alphanumeric information that has been used in the past.

6. Software Interface

The software interface, if standardized, will provide a graphics programming system that offers the advantages of high-level support and facilities to meet the unique technical requirements for multifunction displays and controls. In addition, other advantages are:

- Reduced cost of programming.
- Increased assurance of software reliability.
- Reduced cost through ease of modification.
- Portability and reusability through processor and display device independence.
- Improved software through utilization of state-of-the-art, real-time graphics techniques.

The software functional requirements have been divided into the following three groups:

- Hardware evaluation

- Operational requirements
- Support requirements

Operational Software

The AIDS operational software provides the environment in which the application software are run. This environment may be considered a virtual machine with a well-defined software interface, applicable to a wide variety of processor and system architectures. Even when the underlying physical machine changes, the software interface to the virtual machine will still remain the same.

The services provided may be divided into four general categories: executive functions; input/output functions; file system functions; and reconfiguration control. Executive functions include processor and primary memory allocation and intertask communication and coordination. The input/output functions govern all transactions between the AIDS data processor and any external device. File system functions provide access to data organized as units of related information. The reconfiguration control functions maintain alternative sources for critical data and help the applications functions to determine which peripherals are usable.

Support Software

This software is composed of various tools associated with the Naval Air Development Center's Central Computer Complex and includes items needed to develop the operational software. The two most important tools are the AIDS Display Formatter (ADF) and the AIDS Command Formatter (ACF).

The ADF is a system for preparing the AIDS display-driving software. The actual mechanics of translating display formats into display programs are handled by a graphics, real-time display language. In order that these display programs can communicate with the display update programs that are part of the Operational Display Software (ODS), some conventions on naming of the rapid changes will be promulgated. The display update programs will pass the appropriate name to the graphics, real-time display language run-time routines that will search for the name in the record of image structure in order to locate the appropriate modification code to be passed to the Symbol Generator(s). A pictorial representation of the ADF is shown in Figure 2.

The ACF is a translator that accepts statements in the AIDS Command Language (ACOL) and produces data declarations in CMS-2 for inclusion in the data processor source modules as well as data declarations in the microprocessor assembly language for inclusion in the source modules located in the Integrated Control Set (ICS) itself. The ACOL statements completely define the facilities provided to the pilot on the ICS.

The microprocessor assembly language data definitions specify a hierarchical structure of ICS states, along with button labels and button depression responses appropriate to those states. The responses may be internal to ICS (for example, changing an ICS state in response to a button depression) or may involve ICS sending a command to the data processor. The CMS-2 data definitions describe these commands; the definitions cover command code, data sources and command destination. A pictorial representation of the ACF is shown in Figure 3.

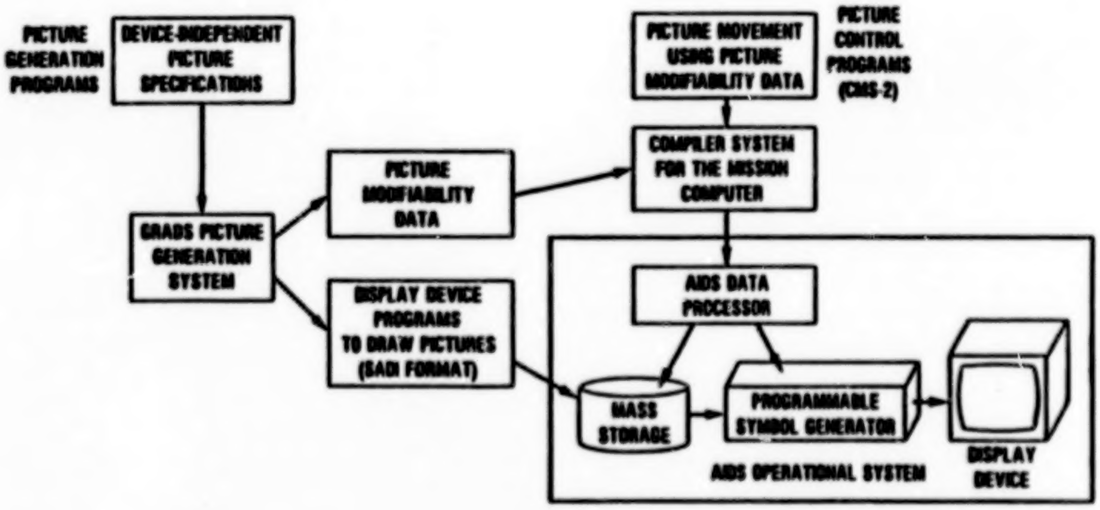
PICTURE GENERATION PROGRAMS
DEVICE-INDEPENDENT PICTURE SPECIFICATIONS
GRADS PICTURE GENERATION SYSTEM
PICTURE MODIFIABILITY DATA
DISPLAY DEVICE PROGRAMS TO DRAW PICTURES (SADI FORMAT)
PICTURE MOVEMENT USING PICTURE MODIFIABILITY DATA
PICTURE CONTROL PROGRAMS (CMS-2)
COMPILER SYSTEM FOR THE MISSION COMPUTER
AIDS DATA PROCESSOR
MASS STORAGE
PROGRAMMABLE SYMBOL GENERATOR
DISPLAY DEVICE
AIDS OPERATIONAL SYSTEM

Figure 2. AIDS Display Formatter (ADF)

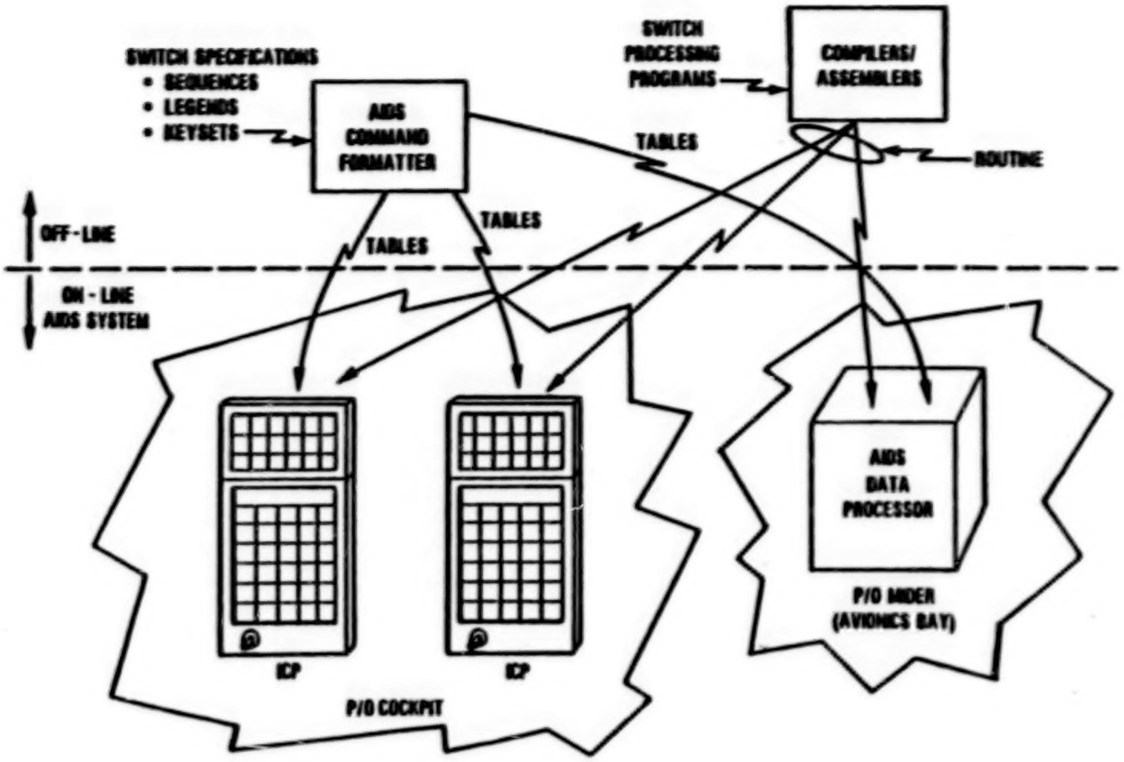
SWITCH SPECIFICATIONS
• SEQUENCES
• LEGENDS
• KEYSETS
AIDS COMMAND FORMATTER
SWITCH PROCESSING PROGRAMS
COMPILERS/ ASSEMBLERS
TABLES
ROUTINE
TABLES
TABLES
OFF-LINE
ON-LINE AIDS SYSTEM
AIDS DATA PROCESSOR
P/O MIDER (AVIONICS BAY)
ICP
ICP
P/O COCKPIT

Figure 3. AIDS Command Formatter (ACF)

CONCLUSIONS

Military airborne platforms of the 1990's will require an expanded and reliable human-machine interface with crew station instrumentation in order to optimize the tactical position of the pilot. State-of-the-art advancements in display hardware and in software and interface designs are critically needed to achieve weapon system crew station instrumentation that is adaptable to many platforms. The display and control interfaces, as shown in Figure 1, portray the four crew station hardware interfaces, the human-machine interface, and the software interface that would meet these needs.

However, as new and improved hardware and software become available, the life-cycle costs must be reduced in order to achieve the necessary operational effectiveness of the future weapon systems. Rigid controls in the design and integration of the six interfaces is crucial to the reduction of life-cycle costs previously described. Reduction of these costs will be the only way that these systems will be introduced. An improvement in the effectiveness, adaptability, and supportability of crew station instrumentation, described in the Background will, of course, be possible only if these innovative concepts are indeed introduced into the fleet. To attain the desired mission requirements, the specification, production and control of these six interfaces must be established to achieve crew station compatibility for multiplatform applications.

SESSION 4

MAN-SYSTEM INTERFACE TECHNOLOGY

N85 14819

HUMAN FACTORS IN COCKPIT AUTOMATION

Earl L. Wiener

University of Miami
Coral Gables, Florida

THE MARCH TOWARD AUTOMATION IN AVIATION

The rapid advance in microprocessor technology has made if possible to automate many functions that were previously performed manually (or not at all). There are various motivations for the march toward automation.

FUNDAMENTAL QUESTIONS

But automation is not without its price. The insertion of automatic devices into man-machine systems inevitably raises questions, among them these four fundamental questions, which probably apply to helicopters as well as transport aircraft.

EXAMPLES OF AUTOMATION-INDUCED ACCIDENTS AND INCIDENTS

Some of the problems can be illustrated by looking at aircraft accidents and incidents that can be thought of as automation-induced, including the following examples. (The first and third examples are discussed in Wiener and Curry, 1980).

IDENTIFIED RESEARCH AREAS

We have identified several research areas, which we believe are basic to the question of the implementation of automation in the cockpit. A further discussion of possible research areas can be found in the report on the NASA/Industry workshop on automation (Boehm-Davis, Curry, Wiener, and Harrison, 1981).

WARNING AND ALERTING SYSTEMS

One of the identified areas deserving further research is warning and alerting systems. Modern transport aircraft have had one after another warning and alerting systems added, and computer-based cockpit systems make it possible to add even more. What is badly needed is a systemwide approach to warnings, not further one-at-a-time proliferation.

CAUTION ALERTS AND WARNINGS

The proliferation of warnings and alerts are illustrated in this table, which indicates by aircraft type the number of such warnings and alerts. There is no reason to think that the same thing will not happen in helicopters.

MAJOR PROBLEM AREAS

Three major areas of concern are input methods (including voice, keyboard, touch panel, etc.), output methods and displays (from traditional instruments to CRTs, to exotic displays including the human voice), and training for automation. It appears at this point that training for operating highly automatic systems requires considerably more attention than it has received in the past.

INPUT

On the input side, considerable work must be done on how to get information into the system. At this time, human voice input is receiving a lot of attention, but it has its many limitations, and may not prove to be the answer.

Keyboards have found their way into the cockpit - modern cockpits have often more than one set of keyboards, and there are many problems, including just old-fashioned "typing errors," keyboard lockup, and error correction. Also, there are questions of just how to turn it all off and either fly manually, or start all over with programming. Certainly better human-computer dialogues are needed.

OUTPUT

On the output side, human factors specialists and designers must examine the problem of information glut. Digital devices make it easy to overload the pilot with information, and designers to date seem unable to resist the temptation. Pilots feel bombarded with information, and long for simpler displays. The challenge is not how to display information, but to discover just what information is needed, can be used, and how to economically display it.

TRAINING

Training methods have not kept pace with the advent of flight-deck automation. We have at one end highly sophisticated and highly expensive flight simulators. At the other end, we have traditional classroom devices, such as blackboards, slides, movies, and static mockups. There is a gulf in between, and it is in this gulf, which includes such devices as CAI and interactive video disks, that the solution to training for dynamic devices will lie.

WHERE DO WE GO FROM HERE?

So in summary, we can ask where we go from here. There are of course many directions. The following are seen as the most urgent and fruitful areas. The first two are traditional research areas in human factors — but the digital devices now available and those planned for the near future make it essential that the input-output ensemble again be reexamined.

As mentioned previously, the helicopter pilot will soon find himself bombarded with information, and overloaded cognitively with the need to make rapid decisions and input their results. Here he again needs help from machines, and the growing area of decision support (expert systems) deserves our attention.

Somewhere in the future, machines will be developed that mimick human reasoning power. This goes far beyond decision aiding, and allows machines to algorithmically work out (and presumably implement) solutions, based on information available in databases, and inputted by human operators. Just how soon this will be available for practical applications such as the helicopter flightdeck is difficult to predict. In the meantime, decision support systems offer more immediate help.

SLIDES

The following slides illustrate advanced graphic techniques for displaying multivariate information. They are illustrative of what must be done in airplane and helicopter instrumentation — the development of graphics, rather than rows of dials or arrays of numbers that must be digested by the pilot.

1. A graphic representation of a household in Florida, and its potential for use of electrical power. (Gitlow and Stewart, unpublished.)

2. Chernoff faces, which offer multi-dimensional graphic presentations. This illustration from Naveh-Benjamin and Pachella, 1982.

3. Graphic warning displays used in nuclear power plant control. The shape of the octogon changes as the individual dimensions change. Set point limits can also be displayed, and deviations beyond the set points easily interpreted. Copyright, Westinghouse Corp.

4. There is always some danger that the system will be overloaded with devices, as illustrated in this cartoon.

REFERENCES

1. Boehm-Davis, D.A., Curry, R.E., Wiener, E.L., and Harrison, R.L., Human factors of flight-deck automation --- NASA/Industry workshop. NASA Tech. Memo. 81260, Moffett Field, CA, January 1981. Also to be published in Ergonomics, 1983, 26, 953-961.

2. Gitlow, H. and Stewart, J., The use of pictorial scenarios to graphically represent points in K-dimensional space. Unpublished paper, University of Miami, 1982.

3. Naveh-Benjamin, M. and Pachella, R.G., The effect of complexity of interpreting "Chernoff" faces. Human Factors, 1982, 24, 11-18.

4. Wiener, E.L. and Curry, R.E., Flight-deck automation: Promises and problems.NASA Tech. Memo. 81206, Moffett Field, CA, June 1980. Also published in Ergonomics, 1980, Vol. 23, 995-1011, and in Hurst, R. and Hurst, L.R. (eds.), Pilot Error. New York: Jason Aronson, 1982.

THE MARCH TOWARD AUTOMATION IN AVIATION

0 MICROPROCESSOR TECHNOLOGY HAS MADE IT POSSIBLE

0 INCREASED SAFETY

0 ECONOMY

0 FLIGHT MANEUVERS AND PRECISION PREVIOUSLY NOT POSSIBLE

0 WORKLOAD REDUCTION

0 MILITARY REQUIREMENTS - WIDE VARIETY OF WEAPONS TO BE DELIVERED

FUNDAMENTAL QUESTIONS

1. QUESTION: WHAT IS THE ROLE OF THE HUMAN IN HIGHLY AUTOMATED SYSTEMS?

2. QUESTION: CAN WE AUTOMATE HUMAN ERROR OUT OF THE SYSTEM?

3. QUESTION: ARE THERE UNDESIRABLE CONSEQUENCES TO AUTOMATION, AND IF SO, WE CAN WE DO TO REDUCE OR ELIMINATE THEM?

4. QUESTION: IS WORKLOAD ACTUALLY REDUCED BY AUTOMATION, OR POSSIBLY JUST RELOCATED OR REDEFINED? IS IT INCREASED IN THE AGGREGATE?

EXAMPLES OF AUTOMATION-INDUCED ACCIDENTS AND INCIDENTS

0 NORD 262 AUTOFEATHER

0 DC-10 HIGH-ALTITUDE STALL

0 INS INPUT ERROR

0 DC-9-80 FUEL MANAGEMENT PROBLEM

From E. L. Wiener and R. E. Curry, "Flight-deck automation: Promises and Problems," Ergonomics, October 1980.

TABLE 1.- GENERALIZATIONS ABOUT ADVANTAGES AND DISADVANTAGES OF AUTOMATING MAN-MACHINE SYSTEMS.

Advantages	Disadvantages	Questionable	Unknown
Increased capacity and productivity Reduction of manual workload and fatigue Relief from routine operations Relief from small errors More precise handling of routine operations Economical utilization of machines (e.g., energy management) Damping of individual differences (narrower tolerances)	Seen as dehumanizing: lower job satisfaction; consumer resistance Low alertness of human operators Systems are fault intolerant — may lead to larger errors Silent failures Lower proficiency of operators in case of need for manual takeover Over-reliance; complacency; willingness to uncritically accept results False alarms Automation-induced failures Increase in mental workload	Overall workload reduced or increased? Total operational cost increased or decreased? Training requirements increased or decreased? Reduction in crew size?	Capital acquisition costs Use of common hardware (e.g., standard mainframe computers) Maintenance costs Extent of redundancy necessary and desirable Long-range safety implications Long-range effect on operators and other personnel (including physical and mental health, job satisfaction, self-esteem, attractiveness of job to others entering field) Long-range implications for collective bargaining Implications for civil liability (e.g., software error resulting in an accident)

IDENTIFIED RESEARCH AREAS

- AUTOMATION OF FLIGHT CONTROL FUNCTIONS
- HUMAN MONITORING BEHAVIOR IN COMPLEX SYSTEMS
- HUMAN BEHAVIOR WITH ALERTING AND WARNING SYSTEMS
- RETENTION AND LOSS OF OPERATIONAL SKILLS
- PSYCHOSOCIAL ASPECTS OF AUTOMATION

(FROM WIENER AND CURRY, 1980)

WARNING AND ALERTING SYSTEMS

- COGNITIVE OVERLOAD
- NONSENSE MESSAGES AND UNHEEDED MESSAGES
- LOGIC TOO COMPLEX
- TRIGGER MODES UNCLEAR TO CREW
- CONFLICTING AND OVERLAPPING MESSAGES
- OVER-RELIANCE ON VOICE IN THE FUTURE?

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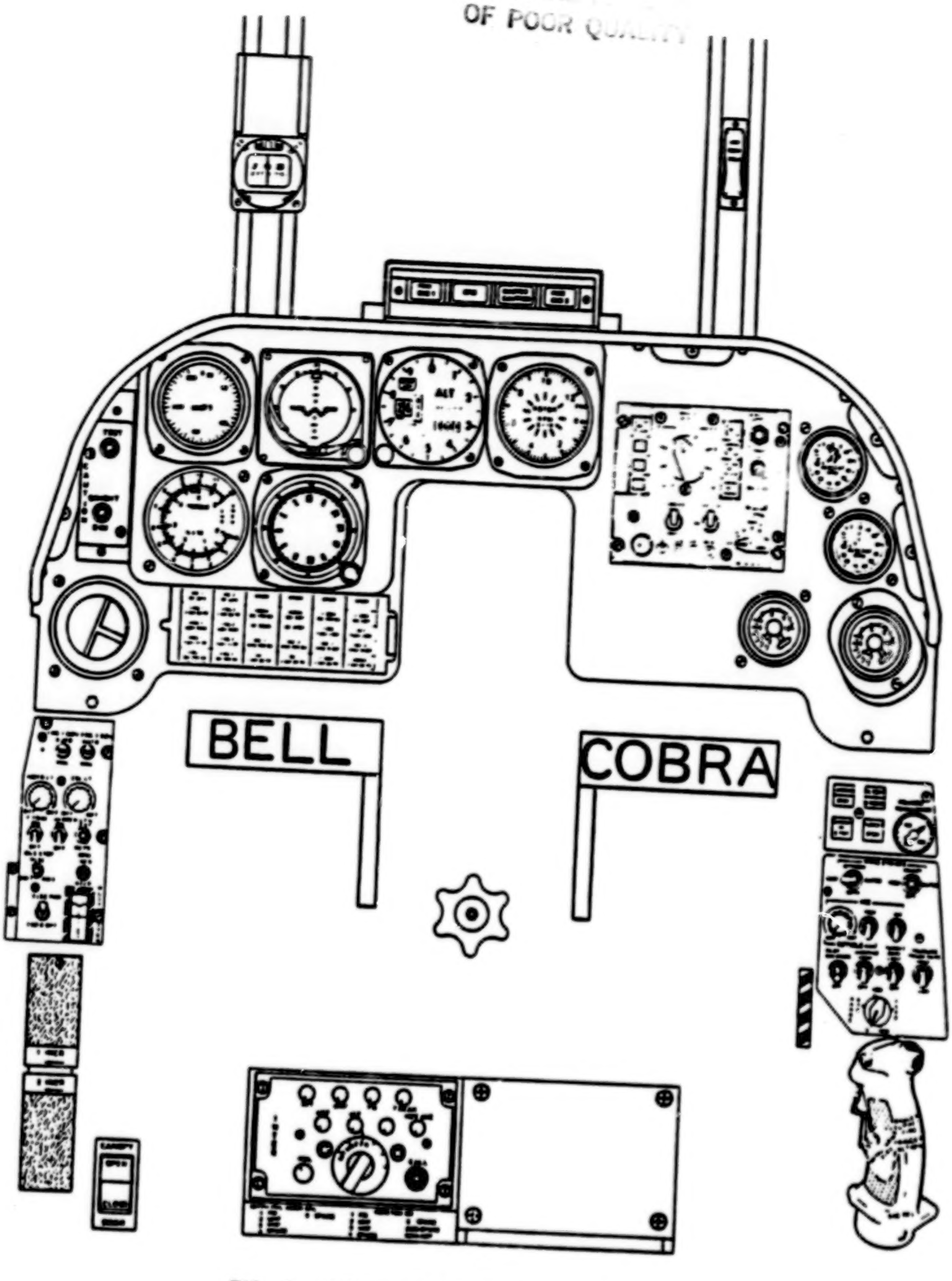
ALT
BELL
COBRA
CANOPY
OPEN
CLOSE

FIG. 3 GUNNER CREW STATION AH-1T

C-4

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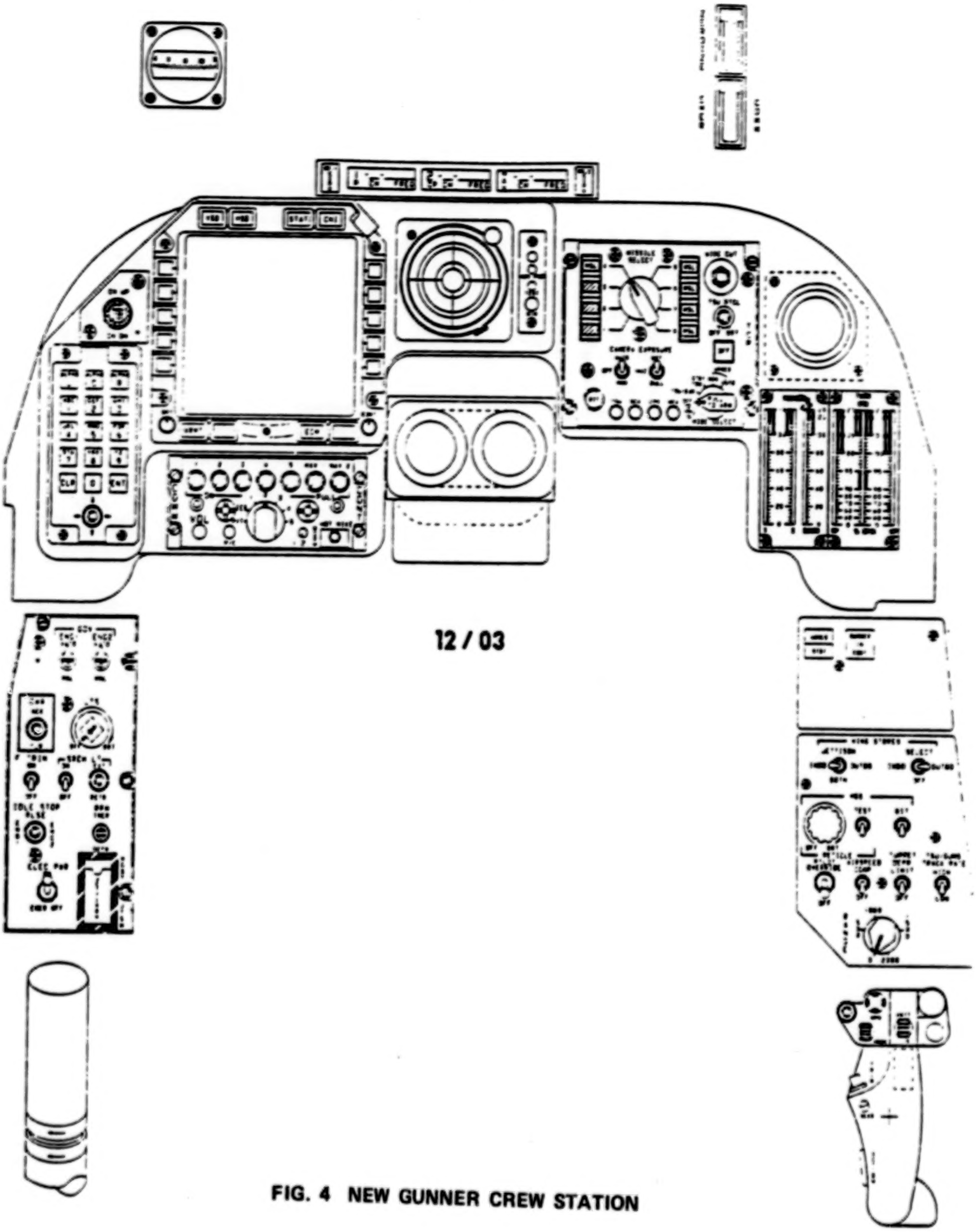
12 / 03
CLR
ENT

FIG. 4 NEW GUNNER CREW STATION

GENERAL COCKPIT ARRANGEMENT AND SWITCHOLOGY DESCRIPTION

When comparing an existing AH-1T pilot cockpit with the newly developed version, it is readily apparent much of the existing clutter has been eliminated. Through extensive use of multiplexing, the addition of ANVIS compatible lighting, vertical scale instruments, a multifunction display (MFD), a full function heads-up display (HUD), and an aural alerting system, crew workload has been reduced and aircraft capability has been increased.

The full function HUD combines the previous functions of the reflex sight and pilot steering indicator and allows the pilot to view a weapons sighting device or flight instrument display as he deems necessary. The increasing demand on helicopters for nap-of-the-earch (NOE) flight has dictated the inclusion of new equipment such as the full function HUD to allow the pilot every opportunity to complete the assigned mission with his vision directed outside the cockpit as much as possible.

The multiplexing of most of the radio control heads has two major benefits. The primary benefit is the workload reduction gained by controlling the communications radios from the cyclic and collective. The second benefit is over twenty inches of unused space on the right side panel that allows for growth, as can be seen on the pilot crew station drawing (Fig. 2).

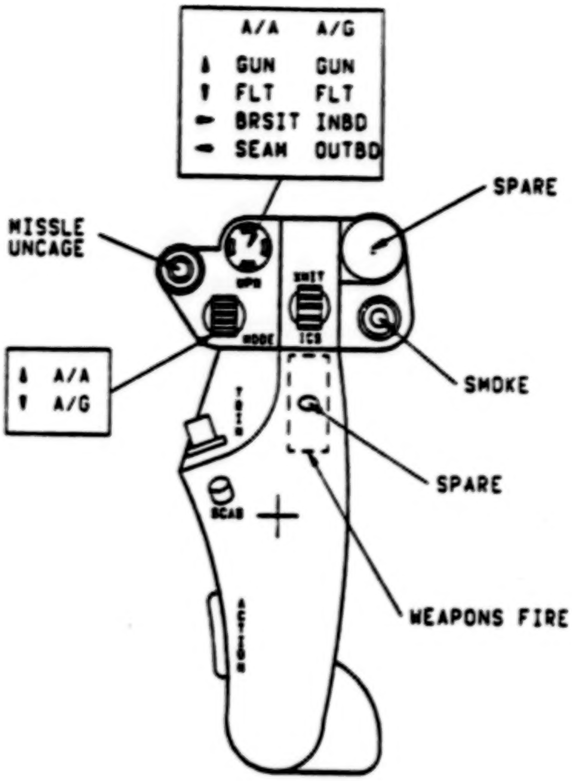
A/A A/G
▲ GUN GUN
▼ FLT FLT
◄ BRSIT INBD
► SEAM OUTBD
SPARE
MISSLE UNCAGE
WPN
XMIT
ICS
MODE
▲ A/A
▼ A/G
SMOKE
TRIM
SPARE
SCAS
WEAPONS FIRE
ACTION

FIG. 5 CYCLIC GRIP

A new cyclic grip has been added to incorporate additional "hands-on" functions for the pilot and copilot/gunner. The XMIT/ICS switch is a two-position switch spring-loaded to OFF. Pushing forward will transmit on the selected radio frequency while an aft movement will activate the intercommunications circuit. The Weapon Select Switch (WPN) is a four-position left-right-fore-aft switch spring-loaded to OFF. A forward movement will select either fixed or Helmet Sight System (HSS) controlled 20mm gun turret. An aft movement will cause the MFD and HUD to display a vertical situation display (VSD).

A right movement, when in the air-to-ground mode, will select inboard wing stores or boresight when the air-to-air mode has been selected. A left movement when in the air-to-ground mode will select the outboard wing stores and SEAM when air-to-air is in use. The upper left MISSILE UNCAGE switch is a

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momentary switch that places the AIM-9 seeker head in the boresight (BRSIT) or search-and-acquisition mode (SEAM) alternatively. The MODE select is a two-position fore-and-aft movement switch spring-loaded to the OFF position. An upper movement allows selection of air-to-air weapons and a downward movement allows selection of air-to-ground weapons. The TRIM and SCAS buttons retain the same function as the existing AH-1T cyclic grip. The ACTION bar retains the existing AH-1T functions. All weapons, with the exception of the TOW missile, are fired from the trigger switch. The upper right switch position will be capped and not used at this time. Provisions therefore exist for growth, such as map waypoint designation or other functions as necessary.

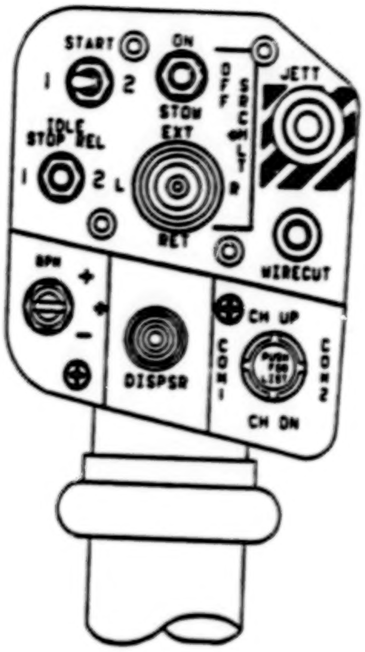

FIG. 6 COLLECTIVE HEAD

A new collective head has been designed to give the pilot increased "hands-on" control of the different systems. The START, IDLE STOP, governor (RPM), searchlight (SRCHLT), ALE-39 dispense (DISPSR), jettison (JETT) and TOW WIRE-CUT switches retain the same functions as on the existing AH-1T. The addition of the communications control switch to the collective head gives the pilot hands-on capability to select different transceivers and frequencies without removing his hands from the controls. The Communications Control switch is a five-position (forward-backward-right-left-push) switch. Holding the switch in either the fore or aft position will cause the transceiver channel to count up or down. The rate of channel change is proportional to the amount of pressure applied to the switch. Releasing pressure on the switch will cause the transceiver to tune the new frequency after a one-second delay. If the dedicated FM-only radio was selected, it would only cycle through those preset channels assigned an FM frequency. A right or left movement of the switch would select either transceiver one or two as the active radio for tuning or transmitting. Pushing down on the Communication Control switch will cause the frequency list MFD page to be displayed. The Remote Frequency Display (RFD) operates in conjunction with the Communication Control Switch.

General Cockpit Arrangement Explanation - Copilot/Gunner.

The multiplexing of the gunner's cockpit has given the front seat an increased capability to function as a copilot as well as enhanced his weapons deployment ability. Through the use of the MFD, a variety of interactive information from the armament, communications and subsystems monitoring sensors can be displayed independently in one or both cockpits. The gunner will now have access to all the communications radios, the TACAN radio, systems status and complete caution/warning information.

N85 14827

AVIONICS SYSTEM DESIGN FOR REQUIREMENTS FOR THE UNITED STATES COAST GUARD HH-65A DOLPHIN

By

Cdr. David A. Young
Sikorsky Aircraft
Stratford, Connecticut

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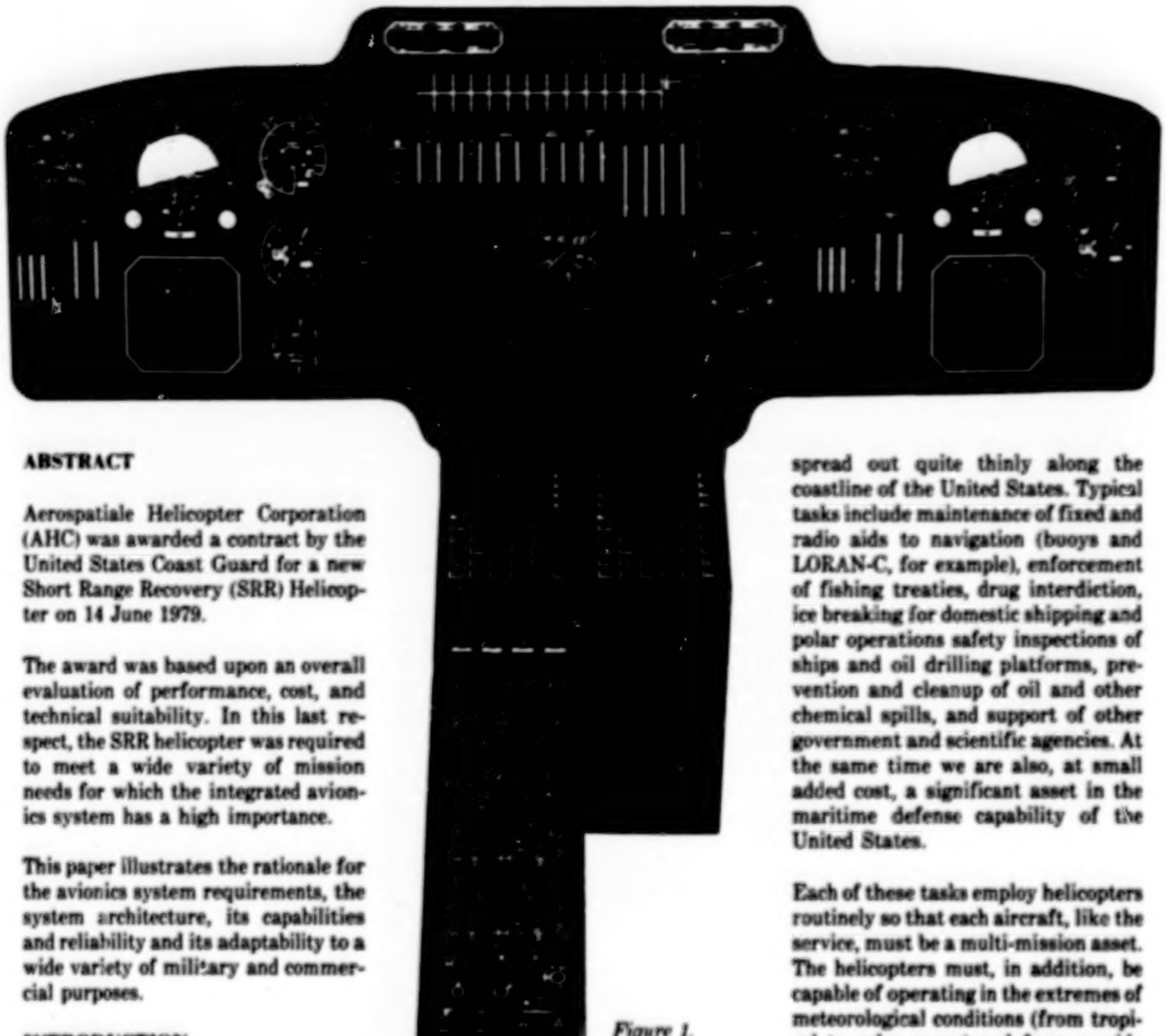

Figure 1. HH-65A Instrument Panel

ABSTRACT

Aerospatiale Helicopter Corporation (AHC) was awarded a contract by the United States Coast Guard for a new Short Range Recovery (SRR) Helicopter on 14 June 1979.

The award was based upon an overall evaluation of performance, cost, and technical suitability. In this last respect, the SRR helicopter was required to meet a wide variety of mission needs for which the integrated avionics system has a high importance.

This paper illustrates the rationale for the avionics system requirements, the system architecture, its capabilities and reliability and its adaptability to a wide variety of military and commercial purposes.

INTRODUCTION

The mission of the United States Coast Guard is to protect lives and property at sea. Within this broad scope of responsibility, the new HH-65A helicopters, being procured under a recently awarded contract to Aerospatiale Helicopter Corporation (AHC), will find a variety of applications for a service which prides itself on its adaptability and multi-mission service to the public. This paper briefly discusses how the HH-65A avionics system requirements relate to these missions, the system architecture, reliability aspects, and specific capabilities.

The most well known activity of the Coast Guard is its search and rescue role. While it may be the most demanding, from the standpoint of equipment, manning, and reliability requirements, our resources must be consistent with several other roles. The majority of Coast Guard forces are spread out quite thinly along the coastline of the United States. Typical tasks include maintenance of fixed and radio aids to navigation (buoys and LORAN-C, for example), enforcement of fishing treaties, drug interdiction, ice breaking for domestic shipping and polar operations safety inspections of ships and oil drilling platforms, prevention and cleanup of oil and other chemical spills, and support of other government and scientific agencies. At the same time we are also, at small added cost, a significant asset in the maritime defense capability of the United States.

Each of these tasks employ helicopters routinely so that each aircraft, like the service, must be a multi-mission asset. The helicopters must, in addition, be capable of operating in the extremes of meteorological conditions (from tropical to polar areas) and from a wide base of operations (land based stations and from ships). Furthermore, the helicopters must be capable of being diverted from one mission to another at a moments notice. The size and weight of the new helicopter was constrained by the types of production helicopters available and the requirement to operate from small ships.

THE AVIONICS ARCHITECTURE

The development of the Avionics System Specification for the HH-65A helicopter was influenced by the Coast Guard's desire to reduce the intense air crew duties during a search and rescue flight. Since the visual search and mission management are best handled by the crew, the routine functions of flight control, navigation, power train management and even routine communications should be relegated to an automatic mode as much as possible.

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These desires and the foregoing operational requirements resulted in the following avionics equipment and architecture specification. Certain equipments are Coast Guard furnished to preserve commonality with standard Navy and Coast Guard systems. Other systems were specified on a commercial brand-name-or-equal basis or purely on a functional basis relying on ARINC or FAA TSO specifications. It was recognized early in the program that aircraft performance (including that of its installed avionics equipment) is the important end product and that such "fly-away" performances are the important parameters to specify. Therefore, FAA certification is the rule, where applicable, and includes Category II IFR approach capability, area navigation precision to the standards of FAA Advisory Circular 90-45A, and all of the attendant safety of flight criteria. Environmental conditions for particular equipment are not specified except that they must be commensurate with the flight condition envelope of the aircraft as a whole. The prospective aircraft manufacturers could, therefore, protect equipment from temperature or other environmental extremes or "harden" them if exposed. In fact, a combination of these two procedures was proposed by AHC.

Appendix 1 is a list of the principal avionics systems to be installed. An immediate reaction to this list might be that it would be impossible to accommodate all of the control heads to operate the equipment. The dilemma which faced the Coast Guard is obvious. The requirement for a large suite of avionics equipment with the practical constraints of weight and volume imposes the necessity to use extraordinary means to make all this equipment fit. Yet, the fleet size of 90 helicopters cannot support a large development cost. The Coast Guard also did not wish to equip itself with aircraft or installed equipment which are peculiar to itself and therefore difficult to support in later years.

Furthermore, it was recognized that not all equipment is required for all missions. The Coast Guard design philosophy, therefore, was predicated upon the following basis:

FLEXIBILITY - The system must be able to accommodate growth and change (possible additions or replacements would be a microwave landing system, FLIR, or NAVSTAR/GPS receiver). Electronic interfaces must be standardized.

ADAPTABILITY - The system must lend itself to removal of equipment in a snap-on/off manner to adapt to particular missions or bases of operations. For example, it must be possible to remove certain equipment (such as one or more VOR receivers, LORAN-C receivers, IFF, Loudhailer, Voice Scrambler, VHF-FM transceiver), depending on their mission utility, to increase payload without changing the cockpit configuration.

In consideration of these factors, the Coast Guard specified a system architecture implemented in a manner which:

1. Provides complete redundancy in all primary and most secondary capacities
2. Combines all navigation and communication control and displays functions in the Central Control Display Units (CDU's), Horizontal Situation and Video Displays (HSVD's), and HSVD Control Panel - all of which are dual redundant
3. Utilizes a MIL-STD-1553B multiplex data bus system to integrate individual components

The HH-65A Avionics System which resulted from the competitive procurement is a very integrated and adaptable one. From the pilot's point of view, the cockpit panel and console layout (Figure 1) is very clean and compact. The underlying system architecture bears some examination, however, to appreciate its features.

The heart of the system operation is the Flight Management System (FMS). It interconnects and operates with the navigation sensors, the communication radios, the flight guidance equipment, and special sensors such as the radar, power train sensors and air data equipment. Although the HH-65A avionics system is not completely digital, the multiplex data bus system is essential to the light-weight, efficient operation of the FMS. In its most simplistic form, the data bus system can be depicted as shown in Figure 2.

In this case a single multi-function control-display unit (CDU) transmits and receives data, on a time shared basis, through a shielded, twisted pair of wires called a bus. The content and control of this data, generated at a rate of one million bits per second, is managed by the Bus Controller which contains all the bus control logic, memory, and timing circuits. There may be certain equipment, dedicated to communication, navigation, armament or displays which operate directly on the bus. In this case the CDU communicates directly to these equipments to change modes or frequencies. Other data, in turn, is returned to the CDU or Navigation display for readout to the pilot.

The immediate advantage of a multiplex data bus system becomes apparent when one considers all of the wires for tuning, mode control,and analog data which would be otherwise required to be routed throughout the aircraft. This problem compounds itself as additional communication, navigation, sensor and display equipment is added.

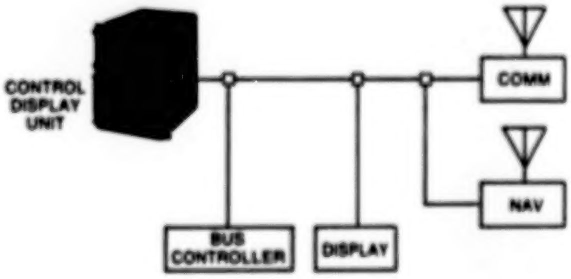

Figure 2. Simplified Data Bus Structure

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Equipment which will connect directly to a multiplex data bus is still rare and it is necessary to provide the proper interface to existing equipment. As a practical matter, it is easiest to combine interface adapters with the bus controller into one unit (which we call a Systems Coupler Unit or SCU). Figure 3 shows how such a unit is added.

In this case, digital control commands from the CDU are converted into, for example, a typical set of "2 out of 5" tuning discretes plus mode discretes to control a VOR receiver. While the analog VOR data might be reconverted to digital data on the bus, it can be wired directly to any electro-mechanical display which also has no bus interface.

The system as shown is obviously not adequately reliable since a failure of either the CDU, the SCU (or its internal bus controller) or the bus itself would cause a complete failure of the whole avionics system. In addition, the CDU is, at any one time, devoted to one control or display function as is the navigation display. To solve this problem, the system is reconfigured as shown in Figure 4.

Another CDU has been added. This allows independent yet redundant control and display of all units. A failure of one CDU does not affect system operation except, for example, that a simultaneous control display of radio frequency and navigation functions is not then possible. The additional parallel data bus, navigation display, and SCU (which includes another bus controller) provide a high mission completion reliability with independent and simultaneous control and display capabilities for two pilots.

A new item, the Mission Computer Unit (MCU) provides specialized services to all other systems on the bus. These services include LORAN-C, VOR and TACAN coordinate conversion, through a Kalman filtered position estimator, into geographic coordinates, RNAV flight plan management (including generation of search patterns), engine and power train condition monitoring and recording, and performance and fuel alert calculations. In addition, the MCU retains a data base consisting of navigation waypoints, listings of local rescue resources, and engine trend data.

This, then, describes the architecture of what the Coast Guard terms a Flight Management System (FMS). Figure 5 is the face of the CDU showing one typical function, communication radio control, in use.

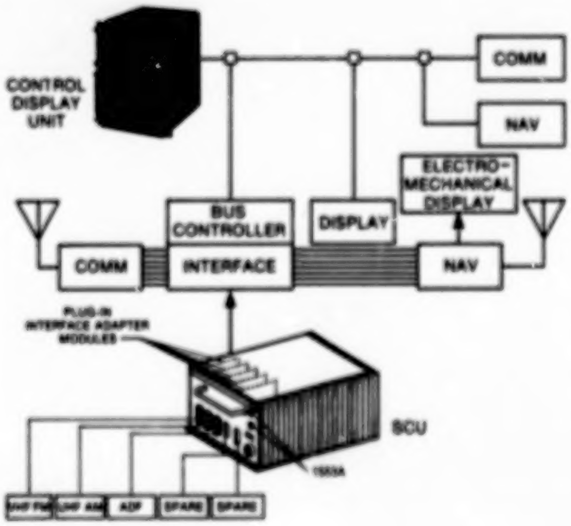
CONTROL
DISPLAY
UNIT
COMM
NAV
ELECTRO-
MECHANICAL
DISPLAY
BUS
CONTROLLER
DISPLAY
COMM
INTERFACE
NAV
PLUG-IN
INTERFACE ADAPTER
MODULES
SCU
1553A
UHF FM
UHF AM
ADF
SPARE
SPARE

Figure 3. Data Bus with Systems Coupler Unit

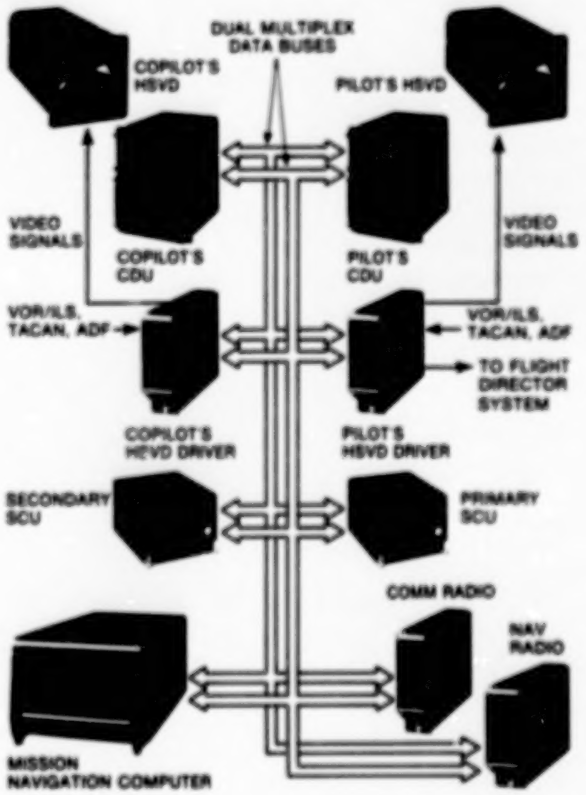
DUAL MULTIPLEX
DATA BUSES
COPILOT'S
HSVD
PILOT'S HSVD
VIDEO
SIGNALS
COPILOT'S
CDU
PILOT'S
CDU
VIDEO
SIGNALS
VOR/ILS,
TACAN, ADF
VOR/ILS,
TACAN, ADF
TO FLIGHT
DIRECTOR
SYSTEM
COPILOT'S
HSVD DRIVER
PILOT'S
HSVD DRIVER
SECONDARY
SCU
PRIMARY
SCU
COMM RADIO
NAV
RADIO
MISSION
NAVIGATION COMPUTER

Figure 4. Dual Data Bus Structure

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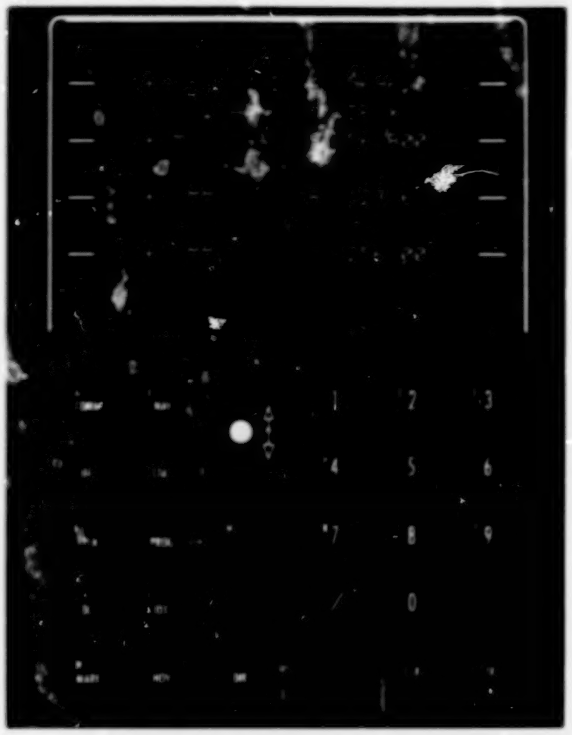

Figure 5. Flight Management System CDU

AUTOMATIC FLIGHT CONTROL SYSTEM

The pilot's effectiveness is much higher if he is not concerned with the helicopter's stability, especially in a low altitude hover at night. The HH-65A Automatic Flight Control System (AFCS) provides hands-off attitude and heading retention, stability/command augmentation for manual flight, automatic trim in all axes, and full coupling to the navigation systems through the flight director. The entire mission can, in fact, be flown automatically through the various flight director modes.

The AFCS uses a combination of limited authority series servos (for high frequency stability augmentation) and full authority parallel servos (for trim and "outer loop" guidance functions). In order to meet Coast Guard requirements for safety, the AFCS is fail-passive: Whenever a failure occurs it causes (1) no perceivable control motion, and (2) positive disengagement and alerting of the pilot. To meet our requirements for mission reliability, each AFCS axis engages individually to permit continued operation of the non-failed axes.

FLIGHT DIRECTOR SYSTEM

The navigation equipment (mission computer, VOR and TACAN) provide flight guidance information to the AFCS through the Flight Director System (FDS). The FDS accepts these inputs and computes pitch, roll, and collective steering commands according to the selected mode, as shown in the following table.

FLIGHT DIRECTOR MODES

HDG SEL	Heading Select
NAV	Navigation (VOR/LOC/BC/RNAV/TACAN)
APPR	Approach (VOR/ILS/BC/RNAV/TACAN)
IAS	Airspeed Hold/Beep
VS	Vertical Speed Hold
ALT	Baro-Altitude Hold
IAS/VS	Airspeed and Vertical Speed Hold (Pitch and Collective)
HOV AUG	Hover Stability Augmentation (Accelerometer Input to Coupled Mode)
T-HOV	Transition to Hover
GA	Go-Around/Auto-Takeoff

These commands are provided to the AFCS for coupled operation and, in addition, they are displayed on the Attitude Director Indicators (ADI's), shown in Figure 6. If any or all of the AFCS axes fail to operate, the pilot may revert to manual flight using these displayed steering commands with little additional workload. This is a reversionary procedure which contributes to mission reliability.

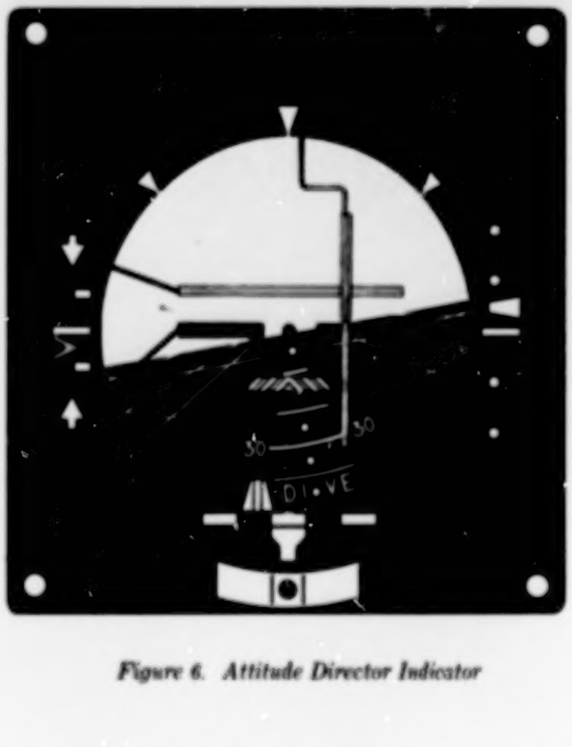

Figure 6. Attitude Director Indicator

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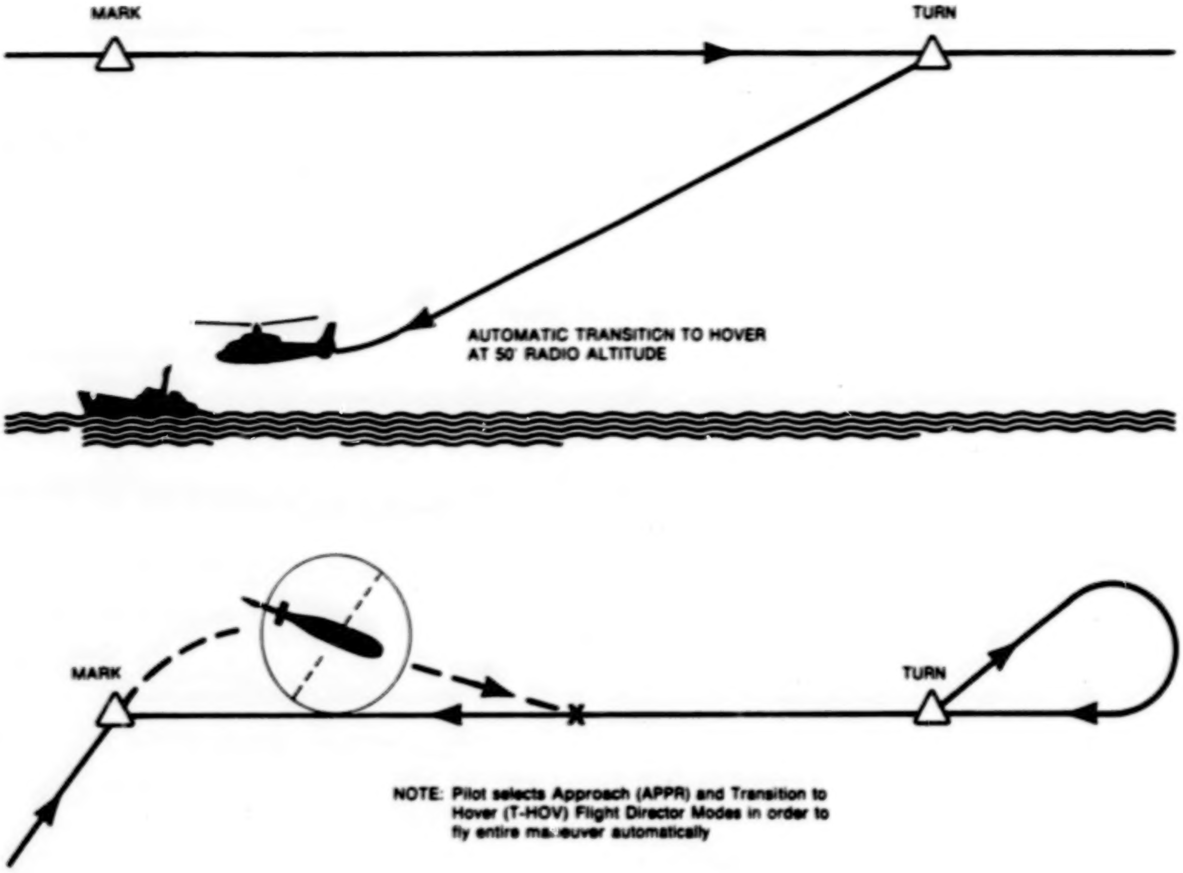

NOTE: Pilot selects Approach (APPR) and Transition to Hover (T-HOV) Flight Director Modes in order to fly entire maneuver automatically

Figure 7. Transition to Hover Profile

The most interesting of these flight director modes is the "T-HOV" or Transition to Hover mode. The pilot selects the Approach (APPR) mode to fly an ILS or RNAV approach in a fairly typical fashion. The FDS provides cyclic and collective commands to capture and follow the approach path at an approach speed which can be modified throughout the approach. "Armed" while in the APPR mode, the T-HOV mode "captures" at 100 feet radio altitude and commands a deceleration to approximately zero groundspeed at 50 feet above the surface of the runway or water. Figure 7 is a profile of the T-HOV mode of approach.

SPECIAL SYSTEMS

The HH-65A will incorporate other equipment which, while not technically new in military systems, is integrated into this system in a unique way.

The aircraft's power train instruments are vertical, electro-optical instruments which are commercial versions of those which are installed in the Army Blackhawk (UTTAS), Navy Seahawk (LAMPS) and Army Advanced Attack Helicopters. The Coast Guard specified an Engine Condition Monitoring System (ECMS) which uses power train data already available in digital form in the instrumentation system and analyzes that data in the computer already existing on the aircraft. The ECMS continually monitors the engine and power train for trends, exceedances, power availability checks; it monitors fuel quantity and alerts the crew when the amount remaining is sufficient only to fly direct to the destination from the helicopters present position, plus reserve. It computes maximum range airspeeds for the current wind and the available power reserve prior to hovering. The ECMS is actually a "function" of equipment already on the helicopter - it is available at no extra cost in weight or additional hardware.

The radar is an adaptation of the Bendix RDR 1300 helicopter radar. The radar antenna has been specified to be larger for higher resolution and detection capability and it employs a digital video integrator to help decorrelate sea return clutter. The actual display of the radar is accomplished on the Horizontal Situation and Video Display (HSVD).

The requirement to display multiple navigation sensor information, flight plan data, and search sensor video, along with a need to keep the instrument panel as small as possible for search visibility, resulted in the specification for a HSVD. This CRT device supplies the navigation and tactical situation and sensor data needed by the crew for each mission phase. Seven display modes and three navigation sources are independently available to each pilot. The display modes include not only a conventional HSI format, but radar, map, and a special hover display which is useful for low altitude, low airspeed, close-in navigation to a spot. It is this hover display which is used to present low range, omnidirectional airspeed from the Pacer LORAS to the pilots.

Provisions for the display of Forward Looking Infra-Red (FLIR) video have been provided so that this equipment can be added to the helicopter in the near future with a minimum of retrofit difficulty. The combined radar-map display, Figure 8, is representative of the flexibility this device has.

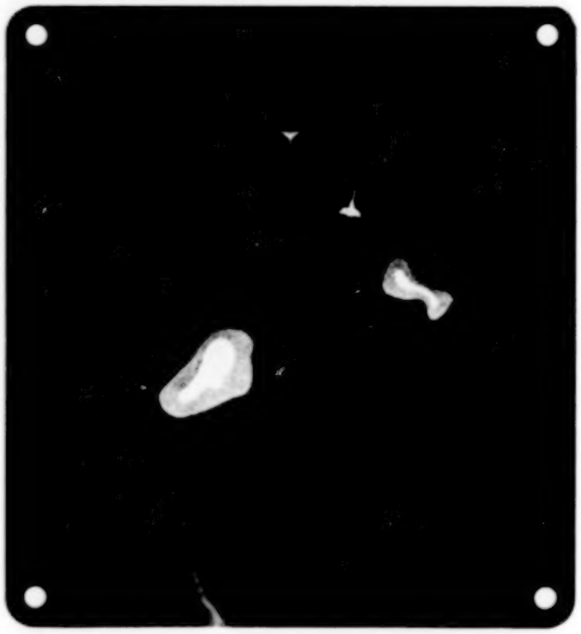

Figure 8. HSVD Radar-Map Mode

CERTIFICATION

The Coast Guard will depend upon the FAA certification process as an acceptance criteria for the aircraft and the avionics system. This means that except for certain military items (such as the TACAN, voice scrambler) all equipment must meet FAA TSO's and must be installed and certified under the aircraft's Type Certification (TC) or a Supplementary Type Certification (STC).

Although the HH-65A avionics system is a synergistically integrated set of individual subsystems, these multiple subsystems will be individually STC'd. With a system such as this, there is a built-in flexibility which will allow other users to select from a large menu of qualified new products depending on their specific requirements. The operator must only determine what capabilities he requires: single or dual pilot IFR operation, area navigation, special instrument approaches, two or three cue flight director, collective assist in the AFCS. . . . and most of this adaption is possible with little apparent change in the cockpit. In fact a fleet of differently equipped helicopters can retain the same cockpit configuration - even as new systems, such as satellite navigation and microwave landing systems, are introduced.

The HH-65A will become operational in the spring of 1982. The Coast Guard has specified a helicopter and an avionics system which is planned to have a long service life. From all appearances, these expectations will be fulfilled, despite changes in missions and technology, for many years.

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APPENDIX 1
INSTALLED EQUIPMENT LIST

COMMUNICATIONS:	
HF Transceiver, 2-30 MHz	Collins 718U-5
VHF/UHF Transceiver	ARC-182 (dual)
VHF-FM Transceiver	Wulfsburg RT-9600
Transponder	APX-100
Voice Scrambler	VP-II
Public Address System	AEM 400
Emergency Locator Transmitter	CIR-11
Acoustic Beacon	Dukane N15F210B
Intercomm System	Pilot, Copilot, Crewmembers
NAVIGATION:	
VOR/ILS/MB	ARN-123 (dual)
TACAN	ARN-118
LF-ADF	COLLINS DF-60
VHF/UHF ADF	COLLINS DF-301
LORAN-C	NSI ADL-82 (dual)
Radar Altimeter	HONEYWELL HG-7502
Air Data	PACER LORAS-1000
FLIGHT GUIDANCE:	
Flight Director	Collins HFCS-800
AFCS	Collins HFCS-800
DETECTION:	
Radar	BENDIX RDR-1300 derivative
FLIR	Display provisions
INSTRUMENTATION AND DISPLAYS:	
ADI	3 cue (dual)
HSI	Collins MFD-80 multifunction display system
BDI	Collins BDI-36
Engine Instruments	Canadian Marconi 730 series vertical-scale electro-optical
Various Others	As required for FAR 29, dual pilot instrument flight
COMPUTER:	
Navigation, LORAN-C coordinate conversion, waypoint memory, engine condition monitoring, fuel alert, mission computer, data link	Collins CAPS-5

D22

N85 14828

THE NEED FOR A DEDICATED PUBLIC SERVICE HELICOPTER DESIGN

Lieutenant Robert Morrison

Commander, Aero Bureau
Huntington Beach Police Department (California)

President
Airborne Law Enforcement
Association, Inc.

PREFACE

It is the proposal of this author that the United States Government, through the established research and management abilities of NASA, provide the necessary funding to research, design and contract the building of an advanced technology rotorcraft that will meet the mission demands of public service (fire, police, paramedics and rescue) operators across the Nation.

Further, that these aircraft and their support will be provided to qualifying federal, state, county and city government agencies on a procurement basis equal to that of the military.

That the primary design of the aircraft will be for civilian use to enhance the ability of their main mission requirement. "The protection of life and property."

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The utilization of helicopters in support of the law enforcement mission has been in effect for approximately 15 years. Early on, after progressive law enforcement agencies saw the advantages of using technology to enhance the safety and ability of the lone police officer on the beat, they began experimenting with this unique aircraft to find the limits of its abilities. Now, 15 years later, it is realized that we have yet to come close to reaching any definable limits of this machine when used as a law enforcement and public service tool (i.e., fire fighting, forestry, ambulatory, medi-vac, etc.).

In fact, the opposite seems to be true. As new technology is developed in the form of ancillary equipment that is adapted to the helicopter, a whole new area of usefulness is unfolded. The appetite is again whetted to refine and seek even greater performance.

Law enforcement is a unique profession that places great demands on an individual officer to perform tasks unrelated to each other in the course of a single shift. A police officer in a patrol car on an assigned beat in a diversified geographic area could find himself or herself pursuing, capturing, defending, searching, photographing, firefighting, rescuing, life saving, climbing, rappelling, shooting, swimming, running, observing, coordinating, analyzing, lighting, announcing, demanding, helping, writing, citing and sometimes dying, alone! They are generalists who have to know how to use the equipment and resources available to them when handling the routine and the emergencies.

Over the years, through use of the diversified abilities of the helicopter, the individual officer has become better able to perform his or her duties more effectively and to an even greater degree, safely. It is a proven tool that has stood the test of time, ability and usefulness. However, it still seems to be unable to overcome the greatest reluctance and the largest objection on the part of many police and public administrators--noise and cost.

The growth of helicopter utilization in public service has been extremely impressive, but unfortunately far below the potential that exists because of the cost/noise factor. Many administrators mistakenly equate the dollar amount of capital equipment to the number of additional men they could hire with the same amount of money.

Progressive and effective police administrators do not necessarily believe that the rise or fall of crime rates are directly proportional to the number of personnel under their command. Technology, in the form of automobiles, radios, telephones, radar and computers have all been instrumental in increasing the effectiveness of the beat officer and limiting the necessity for additional personnel.

Starting a helicopter program is an expensive undertaking that is dreamed of by many and accomplished by few.

The suggestion of implementing a program in an urban area is usually met with resistance from governmental leaders because of the massive capital investment in equipment and initial start-up costs. Reluctance is voiced on the part of the citizenry, due to noise impact and uneasiness centered around invasion of their privacy.

Across the Nation, many programs in existance today are the result of federal grant allocations administered in the early 1970's through the now defunct Law Enforcement Assistance Administration (LEAA). The majority of these helicopter programs, once started with federal assistance, have continued to be supported and operated through local taxes.

Acceptance of these programs many times borders on a love/hate relationship. Many citizens, secure in their homes, accept the noise footprint of a passing police patrol helicopter as the "sound of security." Yet, when it becomes necessary for the patrol helicopter to orbit the scene of a crime for a prolonged period of time, the "sound of security" quickly transcends to a perceived annoyance that further diminishes to utter frustration and contempt.

Most of the equipment presently in use by law enforcement agencies is a product of design technology of the late 1950's, early 1960's. Designs that were conceived for military purposes later found their way into commercial markets and were sold as "new technology." Sporadic attempts were made to decrease the noise footprint of these machines.

Little success was realized, since noise was not conceived as a problem in early designs, and the costs to re-engineer current production aircraft far exceeded what operators were willing to pay in order to become "a good neighbor."

Irrespective of the original design intent, public service agencies have "adapted" early and recent state of the art equipment to their mission responsibilities and through sheer determination have made it work.

Past designs that evolved to present-day state of the art were originally perceived as: Military trainers--TH and OH-13 (Bell 47 Series), TH55 (Hughes 269A), OH23 (Hiller 12-E Series), Scout, reconnaissance and light turbine gun ships (Bell 206 Series), OH-6A (Hughes 369 Series), medium lift transport and gun ship (Bell Hughes Series), Sikorsky CH34, etc.

For a brief period of time, in the early 1970's, present day helicopter manufacturers explored and tested the market for the sale of their products to public service agencies. At first, when funded through grant applications, prospects looked good, and there was a trickle of interest from the manufacturers to expand public service utilization.

Later, through experience, the manufacturers learned that municipal contracts were unpredictable, time consuming and frustrating in their dealings with the ever present bureaucratic "boondoggle." Profits were narrowed by the prolonged marketing efforts that were needed to make a sale. Interest diminished as sales became sporadic, and the thought of public service as a viable marketing arena diminished.

Commercial R and D sought more lucrative markets--oil and executive.

The latest R and D in current production helicopters makes little pretense at targeting public service utilization. Offshore and executive were the dictates of design criteria and, if need be, it can be "converted" to a public use aircraft.

Little thought was given to mission requirements of: hot or midair refueling, hot seating, quick conversion for mission capabilities, noise footprint, 24-hour-a-day operation, hoist accommodations, seat comfort, cockpit environmental control and filtration, fire fighting abilities, visibility, terrain and weather adaptation, electronic and audio-visual sensors, same vehicle for high/low altitude operations, lighting and photographic abilities, to name just a few.

This lack of specific design for public service is not the fault of the manufacturers. They design for a market that will sell enough equipment to recoup their R and D investment and make a reasonable profit. Manufacturers view public service as a potential only if there is an assurance of mass procurement and utilization.

The public service market is a sleeping giant. If uniformly used across the Nation, it would dwarf existing commercial utilization in terms of flight hours and even approach the present day use of this unique machine by the combined forces of the U. S. military. If acquisition is to remain the prerogative of individual governing agencies, this will never happen. It is extremely difficult for an agency to convince an administration of the necessity to expend massive amounts of taxpayers' monies to mount a program that is vaguely understood by most or is envisioned as a white scarf and goggles toy by many.

The massive initial procurement cost of the equipment only gives a small hint to the uninitiated as to the additional ongoing operational expenditures that await.

Construction of a heliport, building or leasing hangar space, parts, maintenance, shop equipment, special tools, insurance, training, all have their impact on the final column of figures that, when added, will leave even the crustiest finance director a little weak in the knees.

All of this has to be sold by a police chief or city administrator as a necessary program solution to an existing problem. And...the City Council or Board of Supervisors are then asked to accept a portion of the program based on faith because of the extreme difficulty involved in measuring some of the intangible results of your proposal.

How do you show, for example, that a burglar, robber or rapist entered your city with the intent of committing his crime specialty and somehow became aware that this individual city was patrolled by helicopter? Having heard stories that these machines were equipped with fantastic night viewing devices, laser beams and gamma ray machines, the perpetrator decides his best move is to drive to an adjoining city that is patrolled by conventional means, where it will be much safer to commit his crime.

Score "One" for the helicopter; but, how do you prove it!

The battle against crime is being fought on a daily basis and on annual budgets by loosely coordinated law enforcement and regulatory agencies who are primarily funded through local taxes, and we are losing!

One reason we are losing is that we do not have the means, resources or technical equipment to mount and sustain a joint attack against crime.

"Crime is an American epidemic. It takes the lives of 23,000 Americans, it touches nearly one-third of American households and it results in at least $8.8 billion per year in financial losses."

"Just during the time you and I are together today, at least one person will be murdered, nine women will be raped, 67 other Americans will be robbed, 97 will be burglarized. This all will happen in the next 30 minutes..."

This recent assessment of the condition of our society was delivered by the President of the Unites States when addressing the opening session of the annual meeting of the International Association of Chiefs of Police, September 26, 1981, in New Orleans, Louisiana.

The audience he was addressing was made up of people who were all too familiar with the realities of the President's remarks. From daily personal experience, they knew that this assessment, though gloomy, did not begin to relate the true depth of the problem.

His speech indicated he had a broad based understanding of some of the problems facing law enforcement, but the chiefs knew that the problem goes deeper than most are willing to admit.

At the same meeting, the Director of the F.B.I., William H. Webster, further illustrated the point in his address by remarking:

"Just a few weeks ago, working with the Drug Enforcement Administration, we arrested over three dozen men and women engaged in massive drug trafficking between Columbia and Florida. We seized, with the help of the I.R.S., $7 million in cash, $11 million in bank accounts, five airplanes, 20 automobiles and a 4,800 acre ranch, all in one day...I do not think the American people fully realize what big business we are talking about."

"In New York City, less than one-sixth of reported felonies ever end in arrests, and ultimately one percent of these felonies end in a prison term for the offender."

Crime, of course, is only one facet of the problem confronted by public service agencies.

Across this Nation, on a daily basis, tragic events occur that make us realize how unprepared we are, even in this modern society, to meet the unexpected forces of nature or the accidental loss of control of our own technology. When nature's forces in the form of fire, floods, hurricane, earthquake, blizzard, windstorm, wreak havoc on entire states, how prepared are we to quickly mobilize to save the lives of innocent victims caught up in the disaster?

Recently, on a winter morning, an entire nation sat warm and snug in their homes while they watched live television coverage of rescue efforts for victims of an ice-covered Potomac River crash of a departing airliner from National Airport in Washington, D.C.

They watched the heroic, yet pitiful, efforts of two men from the United States Park Police as they attempted to rescue the stunned and shocked survivors. Using some of the most advanced equipment available in the form of a helicopter, they were forced to "fish" victims from the water by using a jury-rig of a rope with a life preserver on the end of it. Their hope was that the shocked and freezing victims would have enough strength to hold onto the life ring long enough to be pulled to shore.

One victim, with broken wrists and back injuries, was unable to hold onto the life ring handed to her. Then... only through steel nerves and flying skill did the pilot manage to submerge the landing skids of his helicopter far enough into the water for the observer to pull this victim onto the skid and be lifted to safety.

At that moment the Nation came close to witnessing a second aircraft disaster and the further loss of lives because the tail rotor of this modern-day helicopter was within inches of the water. One slight miscalculation by the pilot would have resulted in a second violent accident.

This was all brought about because these men were forced to use the only equipment they had at their disposal to answer to this emergency call. They were using a helicopter that was not conceived or designed for that type of work. Additionally, they were forced to use a life ring that--if not for the seriousness of the event--would be comical.

The entire rescue effort was late in mobilization, slow in response and handicapped by lack of proper rescue equipment. All of this prompted one of the rescued victims to comment, "I thought they had better equipment than that!"

All of this took place within 10 blocks of the White House.

In the past 15 years, most helicopter programs run by local governmental agencies on a limited funding basis have proven their value and effectiveness. An advanced form of this technology, represented by a single helicopter of modular design, would be capable of performing the multi-mission tasks of the various public service agencies across the entire Nation if provided on a regional basis.

The various branches of the United States Military Services are charged with maintaining the external defense and security of our country. The federal, state, county and city law enforcement agencies are charged with maintaining the internal safety and security of our country. We need equipment that is just as sophisticated, just as effective, and unfortunately just as expensive as that provided to our men in arms.

To say that individual cities or governmental agencies should justify the need and then find the resources to implement a helicopter program is not realistic. Small cities and unincorporated areas cannot afford this perceived luxury. Citizens of these communities pay proportional amounts in state and federal taxes but are unable to undertake massive capital investments in equipment that could only be used on a limited basis. They would, however, be able to afford a proportional share in the total expenses of a regional program.

Any administrator knows that the largest portion of most program budgets is in the cost of personnel. Usually, less than 10 to 15 percent is designated for equipment and operational expenses.

Personnel are already in existance with salaries being paid by public service agencies across the Nation. With minor adjustment and alignment, regional programs could be established on a county, joint county or, in some instances, statewide basis. The choke point is the massive development and procurement funds necessary to provide the equipment that would implement the program.

NASA, being publicly funded, is the logical choice to manage a program of this magnitude. Through their proven management and research abilities, they would provide the developmental studies necessary to achieve the technological advances demanded by public service missions.

The results of this massive R and D would achieve the advances needed by the American helicopter industry to recapture a favorable position in the world marketplace. By contracting the final development of a public service helicopter among existing manufacturers, the burden of production is not placed solely on one manufacturer. Rather, production of parts and assemblies are spread across the country, along with the distribution of jobs and services.

In remarks addressed to a Public Service Helicopter Users' Workshop in July, 1980, Tom Stuelpnagle, retired president of Hughes Helicopters, indicated that public service helicopters currently comprise about one-sixth of the total number of helicopters flying in the United States and because of high utilization, they account for as much as one-third of the civil flight hours.

In a NASA funded study entitled, [1] Investigation of Helicopters in Public Service, it is suggested that by 1990, over 1,450 aircraft would be required to support law enforcement utilization.

In my opinion, this figure is very conservative. Requirements to properly service a federally funded program across the Nation would be a minimum of 2,300 to 2,500 helicopters. Currently, there are in excess of 110 helicopters dedicated to public service operating in the State of California alone. These existing operations cover less than one-third of the State.

Insufficient time and resources prevented undertaking a study on the number of public service helicopters needed on a national basis, but even a cursory glance at local operations gives clues to current high utiliziation by law enforcement agencies.

Orange County, California is one of the smallest counties in geographic size in the State, comprising 798.5 square miles. The population, however, exceeds two million.

For the past 10 years, four cities within Orange County have operated helicopter programs on an efficient and effective basis. A recent polling of these cities indicates examples of potential national utilization. (See Figure 1.)

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[1] R. J. Adams and L. D. King, Investigation of Helicopters in Public Service, Contract number NAS2-10411, November, 1980, by Systems Control, Inc. (Vt.) West Palm Beach, Florida, pp. 3-21 and 3-23.

The nine helicopters used in these programs represent a utilization rate of 1,342 flight hours per aircraft on an annual basis. Of even greater significance is the fact that these programs service only four of 29 cities within the County. The cities operating their own programs represent a little over one-quarter of the population and one-eighth of the geographic area.

The mere fact that these separate programs have sustained ongoing financial support from local taxpayers through city council scrutiny for over 10 years is indicative of productive performance and acceptance of their necessity.

In an arena of rising crime, it is further significant to note that these same four cities enjoy a lower crime rate than their neighbors whose policing methods are conventional.

So, for purpose of illustration, let us assume that a national program could sustain an operational fleet of 2,500 aircraft.

In general terms, at least one-half of the fleet would be dedicated to law enforcement patrol 24 hours a day. This would represent an annual utilization of 10,950,000 flight hours.

Additionally, one quarter of the fleet would assume the remaining public safety functions of fire fighting, rescue, forestry, conservation, ambulatory, surveillance, etc. and fly at least eight hours a day, five days a week. This would produce an additional 1,350,000 annual flight hours and still leave one-quarter of the fleet in reserve for standby, major maintenance and overhaul.

Whichever way you choose to distribute the utilization of these aircraft, the operational figures become astronomical, and the economic benefits to the taxpaying public almost incalculative.

There is no single tool or piece of equipment that can uniformly increase the efficiency and effectiveness of all public service agencies across this Nation than a properly equipped helicopter.

The military has every bell, whistle, gadget and widget conceivable to fight a war, wreak death and destruction and recover their wounded.

The civilian population only has what the local taxpayer can afford to pay in the form of equipment and manpower to extricate themselves from unexpected events.

There is a parallel between equipment provided and needed by the military services and that needed by the taxpayers who ultimately pay for that equipment.

My intent is not to detract from the need or necessity of military appropriations. Rather, to illustrate how thin the "blue line" is between the impression of preparedness and the reality of how totally unprepared we are to cope with the demands of present and future events. It can only be assured with speed and mobility.

1981 Municipal Helicopter Operations

in Orange County, California

CITY	POPULATION	SIZE	NUMBER OF HELICOPTERS	NUMBER OF CREW	TOTAL PERSONNEL	TOTAL FLIGHT HOURS	NUMBER OF YEARS IN OPERATION
Anaheim	230,000	43 sq. miles	2	6	7	2,929	10
Huntington Beach	172,000	28 sq. miles	3	6	9	3,155	12
Costa Mesa	83,500	16 sq. miles	2	6	6	3,175	11
Newport Beach	66,110	16 sq. miles	2	7	8	2,823	9
TOTALS	551,610	103 sq. miles	9	25	30	12,032	

For the first time in the history of our country, aggressive (red nuclear) arms are stored within striking distance of our borders, and the political determinations of neighboring countries are seemingly out of control.

Our frontiers are invaded and impregnated on a daily basis by organized crime, illegal aliens, dope smugglers and contraband dealers using unparalleled sophistication in land, sea and air equipment.

The success of these enterprises is so assured that illicit narcotic dealers are routinely smuggling pure cocaine through our borders in amounts valued at One Billion Dollars for a single shipment. (March 10, 1982, Miami, Florida, U. S. Customs report.) It is acknowledged that smuggling into Florida routinely enjoys a success rate of, conservatively speaking, 90 percent. If this is true, what security is offered to the unprotected coastlines of North and South Carolina, California, Oregon and Washington, to name just a few?

It takes only a casual observer to read and understand that a high degree of sophistication in the use of technology is rapidly increasing for illicit means. If this were not true, how could it be possible for narcotic dealers and illegal aliens to enjoy the freedom and success they have found in penetrating our frontiers.

If war is brought to our borders, even on a limited basis, how prepared are we to cope with continuous, calamitous situations for other than military purposes?

The term "civil defense" in most parts of this Nation is a joke.

Any pretext of preparedness to cope with a massive manmade major disaster in the form of limited terrorist attack, invasion, or nuclear assault would put the civil populace of this country into a complete state of confusion and helplessness.

Coordination, mobilization and rescue efforts could only be possible from the air if roads, homes, communications and utilities were severely disrupted or destroyed.

Admittedly, a dark and sad prospect to discuss, but one we cannot afford to ignore.

The "epidemic" is real. The problem is serious. Public service agencies have to be provided with equipment capable of meeting the demands of this modern space age society.

Years ago, sage advice was uttered by one of our original industrialists, Henry Ford, when he said, "Before everything else, getting ready is the secret to success."

Conclusion

(1) No single investment could better serve the needs of the United States' taxpayer for protection of life and property than an aerial umbrella provided by Public Service helicopters operated on a regional basis.

(2) A federally funded research and development program for civil helicopter utilization would offer economic return on an investment dollar equal to that of the Space Shuttle Program.

(3) A federally funded civil helicopter program directed by NASA would:

   A. Provide a melting pot of R and D technology advantages that would enrich the capabilities of individual United States manufacturers to compete with foreign subsidized contenders.

   B. Provide an opportunity for development of aircraft technology for other than military use.

   C. Assure or increase response times to most emergency situations.

   D. Substantially reduce or surpress the opportunities for criminal activities.

   E. Directly attack and impact illicit narcotic smuggling into the United States.

   F. Reduce the continual need for additional personnel because of advanced proficiency.

G. Provide a catalyst for mutual cooperation between political subdivisions.

H. Provide sustaining job opportunities for:

1. Airframe manufacturers
2. Electronics and instrumentation
3. Communications
4. Engine and power supply
5. Petroleum industry
6. Alloy metal manufacturers
7. Computer industry
8. Training institutes and colleges to instruct:
    a. A and P mechanics and technicians
    b. Simulator technology
    c. Event analysis and dispatching effectiveness
    d. Pilot primary and advanced training
    e. Electronics' technicians
    f. Ground crew maintenance and handling
    g. Fire, paramedic and rescue training
    h. Hospital emergency medical training
    i. Ancillary equipment manufacturers
    j. Governmental coordination and cooperation.

...and, of course, all of this will clearly provide eminent job opportunities and endless possibilities of litigation for our friends in the legal profession.

APPENDIX B

AVIONICS TECHNOLOGY COMMITTEE

CHAIRMAN: DR. J. S. BULL

CO-CHAIRMAN: Mr. R. B. HUNTOON

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AVIONICS COMMITTEE

Chairperson: John S. Bull

Co-Chairperson: Richard B. Huntoon

COMMITTEE MEMBERS	AFFILIATION
Remus Bretoi	NASA-Ames Res. Ctr.
George Callas	NASA-Ames Res. Ctr.
J.J. Cathey	Aerospatiale Helicopter Corp.
Chuck Cole	Harris GASD
Dallas Denery	NASA-Ames Res. Ctr.
Ed Diamond	UTC/Sikorsky Aircraft
Tom Drennen	Sperry-Albuquerque, NM
Jerry Keyser	Edwards Air Force Base
Herman Kolwe	Naval Air Test Center
Eric M. Peterson	Honeywell, Inc.
George Philips	US Army Aviation Ctr.
Cecil Richardson	IBM-Federal Syst. Div.
Jerry S. Seeman	US Army AVRADCOM
Archie Sherbert	Boeing-Vertol Co.
John Swihart	FAA, Helicopter Policy & Procedures Staff

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APPENDIX

Avionics Technology - Systems Concept Committee Report

The Avionics Technology - Systems Concept Committee meeting was called to order at 8:30 AM on Day 2 of the Workshop by Co-Chairmen John Bull and Dick Huntoon. To begin the day's session, each person in attendance introduced himself and the organization which he represented. A detailed list of attendees is included in the Appendix. There were 9 persons from industry, 4 from DOD, 1 from the FAA, and 5 from NASA for a total of 19 persons. The following organizations were represented.

Industry:

Sikorsky
Boeing-Vertol
Aerospatiale
Rockwell-Collins
Sperry
Honeywell
King
Harris
IBM

DOD:

AVRADCOM
Army Aviation Center
Test Wing, Edwards
NARC Pax River

FAA:

Southwest Region

NASA:

Ames Research Center (5)

Agenda

John Bull then proposed the following Agenda of items, which the Committee agreed to as appropriate for the day's activities.

0830	Introduction	John Bull, NASA Ames
0845	Certification of Issues	John Swihart, FAA SW Region
0905	Avionics Integration	Ed Diamond, Sikorsky Airport

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0925	NASA G&N Research	Dallas Denery, NASA Ames
0945	Break	
1000	Review Objectives, Tasks	Open Discussion
1045	Identify Mission Requirements	Open Discussion
1130	Lunch	
1300	Identify Problems, Issues	Open Discussion
1400	Identify Research Areas	Open Discussion
1500	Break	
1515	Identify NASA Research Areas	Open Discussion
1615	Summarize Committee Results	Richard Huntoon, Collins Avionics Division
1700	Adjourn	

Presentations

The first of three presentations to the Committee was given by John Swihart, FAA SW Region, on the subject of Certification of Advanced Systems. Main subjects covered were issues related to Power Supply Systems, Software Control, Lightening Substatiation, and Adequacy of Certification Regulations. The text of his complete presentation is included in the Appendix.

The next presentation to the Committee was given by Ed Diamond, Sikorsky Aircraft, on the subject of "Avionics Integration". Ed discussed the unique problems related to helicopters such as flight control in confined areas, nap-of-the-earth operations, surviveability, slung loads, and remote site operations. He stressed the requirement for more accurate navigation and guidance. Technology areas mentioned were multiplexing, electro-optical sensors and displays, controllers, handling qualities, precision computation, and refined ergonomics. He discussed research areas for NASA which included required simulation levels of fidelity, display symbology, integrated flight control/propulsion, and system graceful degradation. He also discussed FAA credits for certification and the use of simulators for this purpose.

The last of three presentations to the Committee was given by Dallas Denery, Ames Research Center, who provided the Committee with a description of research programs currently being conducted in the NASA Ames Aircraft Guidance and Navigation Branch. Current research programs include work in Helicopter Operating Systems, VSTOL Guidance and Control, Crew Station Design Criteria, Digital Flight Control System Verification and Validation, Aircraft Accident and Safety Analysis, and Advanced Guidance and Navigation Concepts. Copies of viewgraphs used in his presentation are included in the Appendix.

MISSION REQUIREMENTS FOCUS

MISSIONS	SINGLE PILOT	NIGHT	ALL-WEATHER	CAT IIIc LANDING	OBSTACLE AVOIDANCE	WIRE DETECTION	NOE
CIVIL TRANSPORT OFFSHORE, CORPORATE	L	M	M	H	L	L	L
CIVIL EMS	L	H	H	M	M	M	L
SEARCH AND RESCUE	M	H	H	M	H	H	M
LAW ENFORCEMENT	L	H	H	M	H	H	L
MILITARY ATTACK/SCOUT	H	H	H	L	H	H	H

SYSTEM CONCEPT

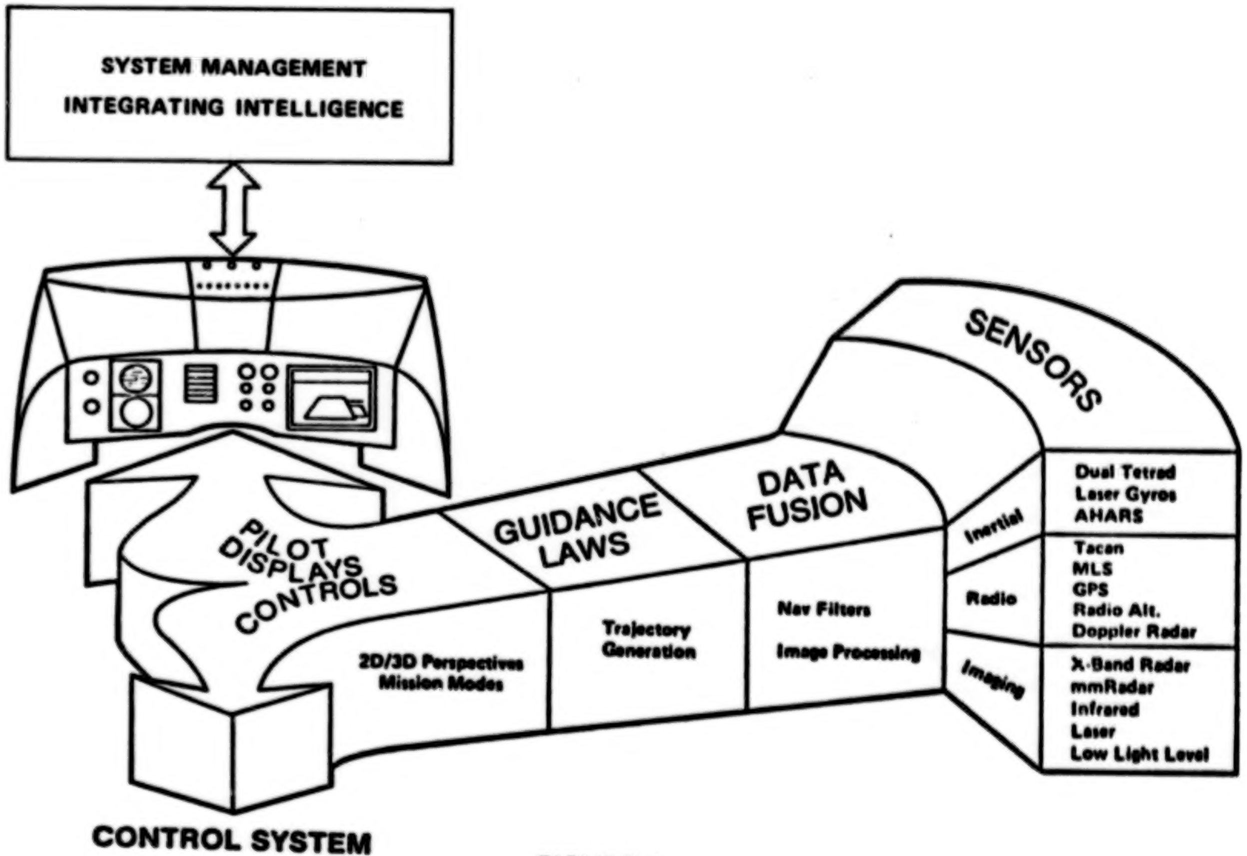
SYSTEM MANAGEMENT
INTEGRATING INTELLIGENCE
PILOT
DISPLAYS
CONTROLS
2D/3D Perspectives
Mission Modes
GUIDANCE
LAWS
Trajectory
Generation
DATA
FUSION
Nav Filters
Image Processing
SENSORS
Inertial
Radio
Imaging
Dual Tetrad
Laser Gyros
AHARS
Tacan
MLS
GPS
Radio Alt.
Doppler Radar
X-Band Radar
mmRadar
Infrared
Laser
Low Light Level
CONTROL SYSTEM

FIGURE 1.

N85 14829

CERTIFICATION OF ADVANCED SYSTEMS

By:

John D. Swihart, Jr.
Aerospace Engineer

Helicopter Policy and Procedures Staff
Federal Aviation Administration
Fort Worth, Texas

July 27, 1983

Presented to:

Advanced Helicopter Cockpit
Design Concept Workshop
NASA, Ames

CERTIFICATION OF ADVANCED SYSTEMS

INTRODUCTION:

The next few years will usher in extremely sophisticated systems designs. Today, we are seeing cockpit management systems, electronic flight instrument systems and electronic fuel control systems, to name a few. Farther along, we see fly-by-wire (FBW) systems.

The basis of this revolution is the microprocessor based programmable digital system technology. So with that technology in mind, let's explore a few areas that are sure to come up in a certification program. Let's look at:

POWER SUPPLY SYSTEM
SOFTWARE CONTROL
LIGHTNING SUBSTANTIATION
ADEQUACY OF CERTIFICATION REGULATIONS

POWER SUPPLY SYSTEM:

Doesn't it seem rather basic that if you are going to develop a latest state-of-the-art system that you need to supply power to those type systems with a power system that has a very high integrity. There really shouldn't be much disagreement on that point. Where the disagreement begins is when we start assessing failures in the system. Our major problems seem to be with the distribution systems, more than the equipment.

Of course, if you assume nothing ever fails, the system can be evaluated quite easily. FAA assumes busses will fail, power feeders will fail, cable and j-box fires do occur, circuit breakers trip and fuses do in fact open just to give a few examples. Many power systems being produced today take very limited or no advantage of existing technology regarding fault clearing and instead rely to varying degrees on the infinite wisdom of the pilot to straighten out the problems when they occur. For the type of systems we are discussing today, this type of thinking has got to change.

The "nothing ever fails" or "let the pilot sort it out" thinking has got to be made a thing of the past. Electrical systems do fail. Our airplane friends are talking very seriously about the all-electric airplane (no hydraulics) and when that occurs, I don't believe the all-electric helicopter will be very far behind. At that point in time, we must have very good electrical power systems.

Additionally, it has been found that many of the current digital systems suffer from temporary functional upset caused by "dirty" power systems. That is, those power systems which allow excessive bus voltage drop during power source switching, have excessive A.C. components on D.C. buses, or excessive high frequency components on the A.C. buses. These problems may be alleviated when equipment manufacturers provide for a greater tolerance of "dirty" power supplies.

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SOFTWARE CONTROL

Currently the most stringently controlled software is that identified as complying with the Critical Category of RTCA Document DO-178. A question that is being asked is whether or not that critical rating is sufficient for full exposure systems, such as FBW.

A good example of a Critical application in service today might be an autoland system. In this case, we have a critical function being accomplished, but the exposure time is very low. In the case of FBW, we have critical functions, and we have continuous exposure. Enough concern exists in this area that a meeting of the RTCA SC152 committee will take place in August at which this issue will be discussed. The outcome of that session could very well be the establishment of another DO-178 category that is above the present critical category.

Some techniques that are being considered for critical applications include dissimilar software, hardware, programmers, and so forth. Some feel the major contribution this type of thinking will make will be limited to that of compounding the design difficulties, and overall impede the development of software-based systems for critical functions. Let there be no doubt about it, we are extremely concerned about the application of this technology to continuous critical functions; however, we hope our concerns and efforts will contribute more than the introduction of development delays. At this point in time, we believe the conventional method of providing redundant systems is not adequate. We believe this because problems with software come from software errors. These errors are not random and if two systems are accomplishing a function, both will be simultaneously affected. Hardware failures are random and this makes an enormous difference. This distinction is significant and it's my feeling after several recent discussions that many at the decision-making level do not understand this distinction.

LIGHTNING SUBSTANTIATION

Most previous designs have only considered the effects of lightning to the extent that the airframe and fuel system are protected, and this seems to have been adequate for those designs. We understand the BV-234's have successfully sustained several strikes that were considered severe.

For digital systems, it is appropriate to go further. Manufacturers are conducting tests generally in accordance with the recommendations of the SAE AE4L committee and extrapolating these results upward. Based on the results of this analysis and testing, the equipment manufacturer will specify system limits and the airframe manufacturer will substantiate that the specified limits are being respected and are not being compromised by his installation. A typical limit might be 500 to 600 volts for equipment.

As we advance further and approach more closely the continuous exposure extreme, it has been suggested by some that a 2:1 factor should be applied to the system manufacturers stated limits. That is, the airframe manufacturer should show that his worst case situation is half that specified by the equipment manufacturer. The other suggestion that at least one natural encounter should be required before approval of systems such as a FBW. Right now we aren't sure about either of these. We will follow closely the accomplishments of our airplane counterparts and will keep in close touch with our National Resource Specialist for digital systems. We believe it appropriate to follow the developments on the airplane side of the house closely and take advantage of their findings if they are transferable to the helicopter side.

The trend toward the use of more and more composites will further complicate the lightning protection problem. Bonding will be more important than ever with the use of more composites. The results of some U.S. Army testing on a helicopter that relies heavily on composites indicates some problems here.

Another point regarding lightning is that whenever any testing is conducted, the system being evaluated must be functioning normally. It seems that some integrated circuits will "latch up" when pulsed and then destroy themselves due to excessive power supply current. Power-off testing will not discover latch up conditions. Also, Fiber-Optics may offer some help with lightning since it appears this technology seems to be more immune to the secondary or induced effects of a lightning strike.

ADEQUACY OF CERTIFICATION REGULATIONS

The primary regulations that will be relied on to evaluate advanced systems will be FAR Sections 29.771, 29.777, 29.1301 and 29.1309. Section 29.771, 29.777 will be the basis for the pilot compartment evaluation. Section 29.1301 will be used to assure, among other things, that the system functions properly when installed. Section 29.1309 of course will be used as a basis to evaluate the environmental considerations and the failure modes.

Section 29.771, 29.777 and 29.1301 should be adequate, however, Section 29.1309 as it presently reads will not be adequate for many applications. A stronger 29.1309 is in order for the more critical systems. In some instances, special conditions may be in order; however, we will try to avoid them.

SUMMARY

FAA's primary goal in evaluating system designs is to help assure the introduction of safe system designs. We also believe developing safe system designs is a primary goal of industry. We look forward to working with industry in developing realistic evaluation criteria and regulation revisions toward the successful introduction of advanced system capabilities into commercial helicopter designs.

SUBJECT: References, John Swihart, FAA

1. "Test Waveforms and Techniques for Assessing the Effects of Lightning - Induced Transients." Report of SAE Committee AE46, December 15, 1981.

2. "Lightning Test Waveforms and Techniques for Aerospace Vehicles and Hardware." Report of SAE Committee AE46, June 20, 1978.

3. C.S. Droste, R.T. Zeitter, J.L. Dabold
"A Lightning Protection Program for the F-16 Fly-by-Wire System."

4. Thomas J. Lange.
"The Application of Nuclear EMP Protection Technology to Lightning Protection Problems." FAA Report No. FAA-RD-79-6, March 1979.

5. J. Anderson Plumer
"A New Standard for Lightning Qualification Testing of Aircraft: Technical Overview, Definition and Basic Waveforms." FAA Report No. FAA-RD-79-6, March 1979.

6. J.C. Bushnell
"Sandia Lightning Simulator." National Atmospheric Electrical Hazards. Interagency Coordination Group Meeting - Dec. 1981

7. David L. Albright
"Lightning Strike Qualification Testing of U.S. Army Helicopters." National Atmospheric Electrical Hazards. Interagency Coordination Group Meeting December 1981.

8. J.H. Shannon and J.D. McDonnell
"Applications of Digital Avionics to Commercial Aircraft; The DC-9 Super 80 and Beyond." 4th AIAA/IEEE Digital Avionics Systems Conference.

9. Michael J. Cronin
"The Role of Avionics in the All Electric Airplane." 4th AIAA/IEEE Digital Avionics Systems Conference.

10. Fred R. Motter
"Electromagnetic Interference Control for Avionics Processors." 4th AIAA/IEEE Digital Systems Conference.

11. M.K. Zaman, Ph.D.
"Fiber-Optic Immunity to EMI/EMP for Military Aircraft." 4th AIAA/IEEE Digital Systems Conference.

AVIONICS INTEGRATION

By

Ed Diamond
Senior Engineer

Sikorsky Aircraft
Stratford, Connecticut

ACHIEVEMENT OF FUTURE BROAD MISSIONS REQUIRES INTRODUCTION OF NEW TECHNOLOGIES

- Multiplexing
- Fiber Optics
- Fly-By-Light/Wire
- Survivable-Redundant Flight Controls Actuation -
- Multifunction Flight Guidance & Control -
- Multipurpose Cockpit Controls and Displays -
- Hostile Environment Invulnerability -

- TECHNOLOGY CONCERNS

- Safety
- Changes
- Attributes
- Murphy's Laws

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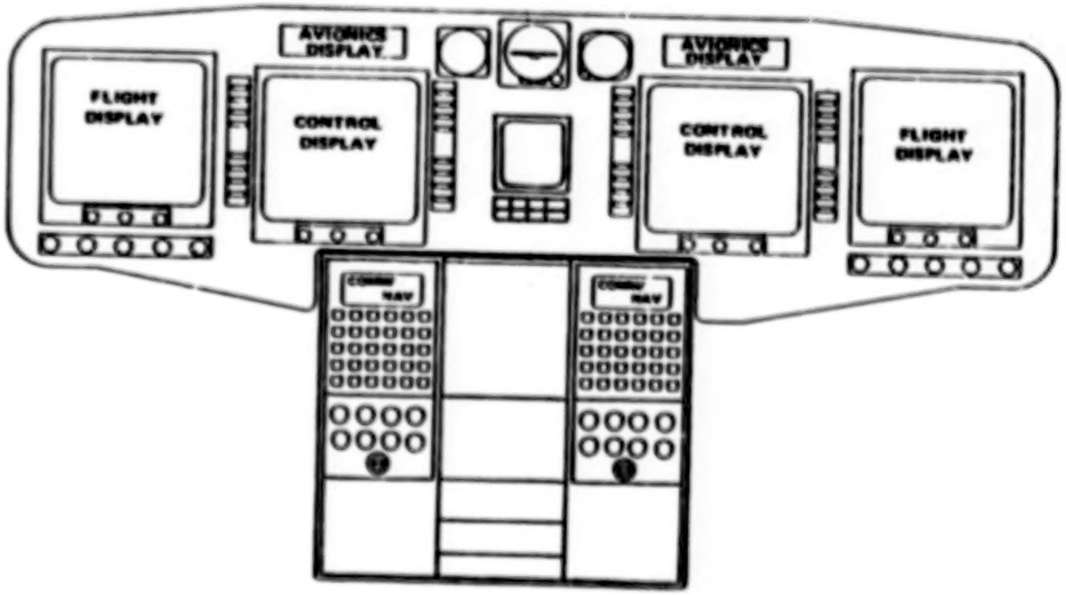
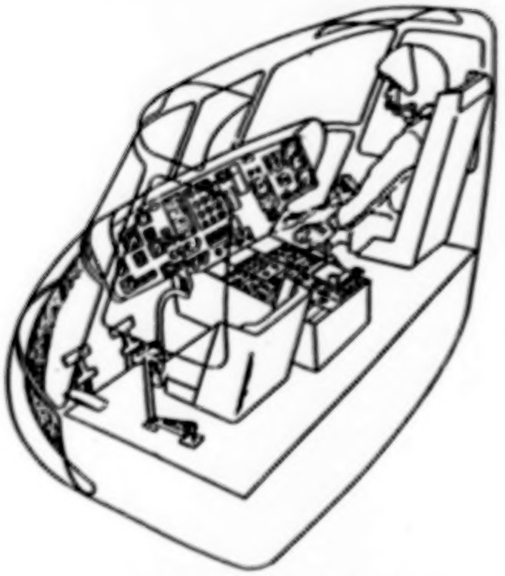
S-76 ADVANCED FLIGHT MANAGEMENT DEMONSTRATOR CONCEPTUAL BASELINE


AVIONICS DISPLAY
AVIONICS DISPLAY
FLIGHT DISPLAY
CONTROL DISPLAY
CONTROL DISPLAY
FLIGHT DISPLAY
COMM NAV
COMM NAV

CURRENT CH-53E COCKPIT

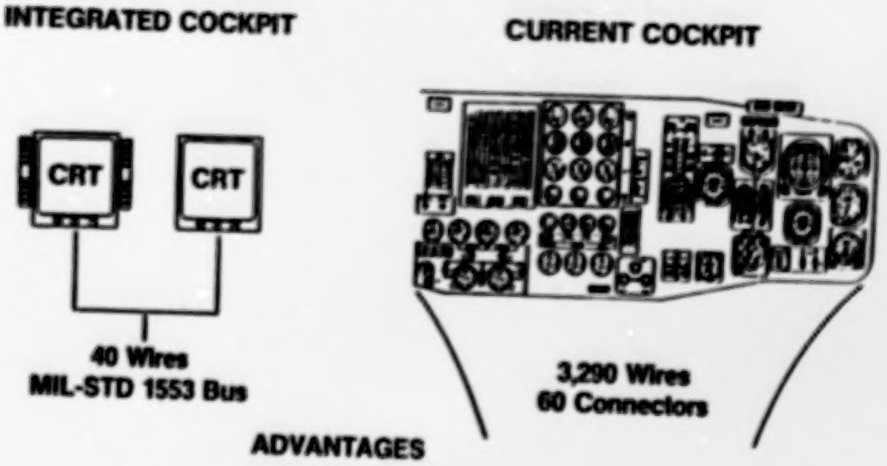


- ~200 displays/switches/knobs
- 7.3 ft.^{2} instrument panel area
- 17° over the nose visibility

- TECHNOLOGIES

- MULTIPLEXING
- ELECTRO OPTIC DISPLAYS
- ADVANCED CONTROLLERS/HANDLING QUALITIES
- PRECISION COMPUTATION
- ADVANCED SENSORS (INSIDE/OUTSIDE)
- REFINED ERGONOMICS

MULTIPLEX DATA BUS



INTEGRATED COCKPIT

40 Wires
MIL-STD 1553 Bus

CURRENT COCKPIT

3,290 Wires
60 Connectors

ADVANTAGES

- Aircraft safety
- Redundancy
- EMI reduction
- Computation consolidation
- Flexibility

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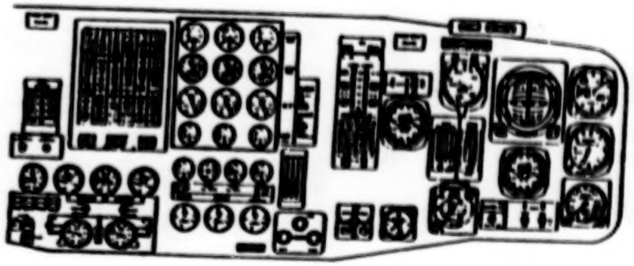
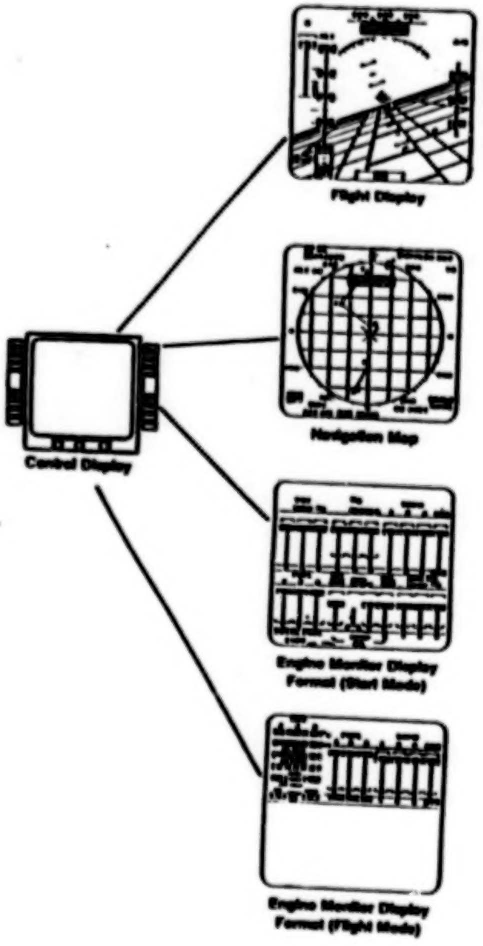
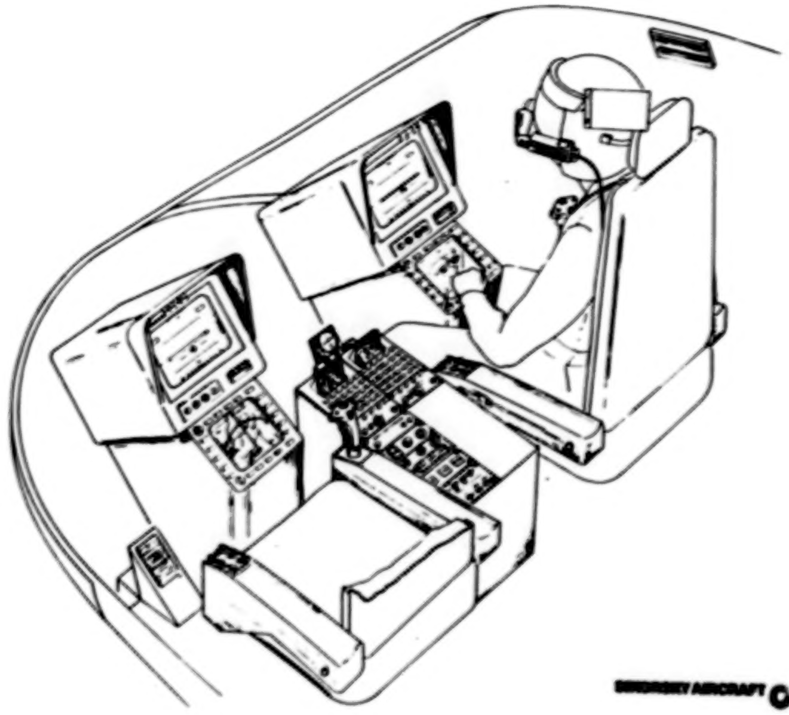
CONTROL
DISPLAY FUNCTIONS




Flight Display
Navigation Map
Control Display
Engine Monitor Display Format (Start Mode)
Engine Monitor Display Format (Flight Mode)

FUTURE HELICOPTER COMMAND AND CONTROL CENTER



SIKORSKY AIRCRAFT

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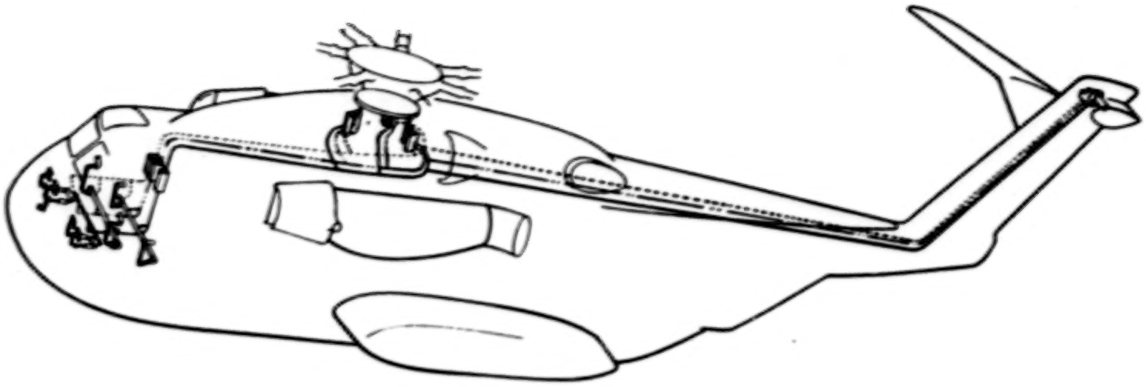
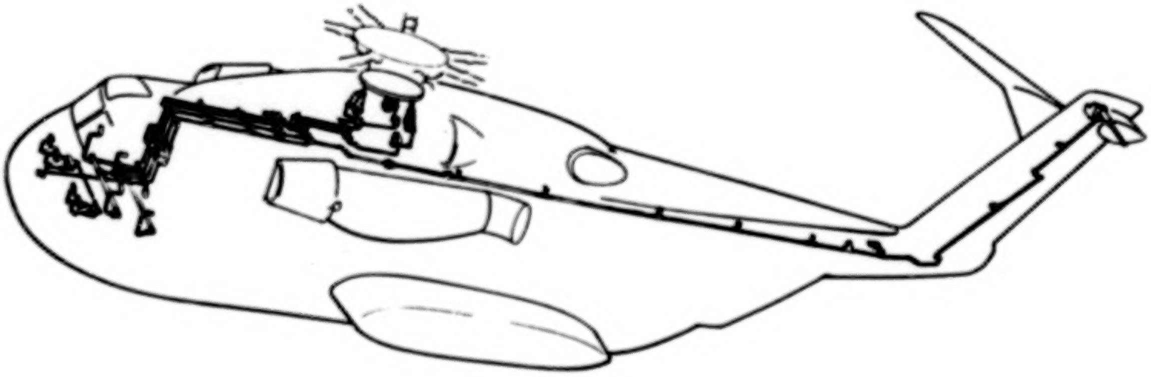
CH-53E FLYBY-WIRE CONTROL SYSTEM



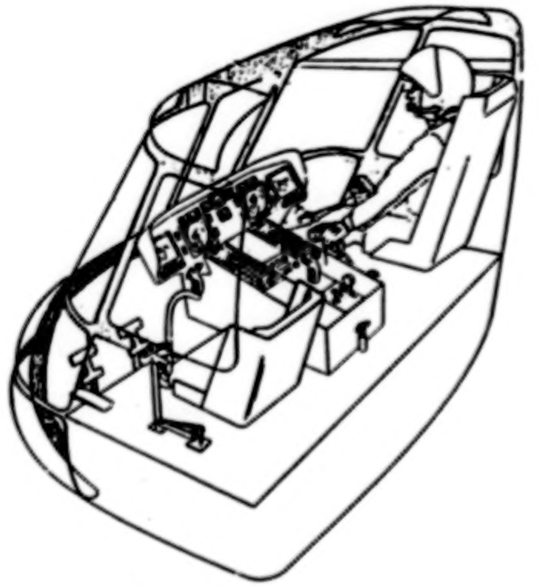
CH-53E EXISTING CONTROL SYSTEM



- COMMERCIAL APPLICATIONS

- STANDARDIZATION
- CERTIFICATION
- SYSTEM PARTITIONING/DEFINITIONS

CH-53E INTEGRATED COCKPIT



- 10 displays
- 5.8 ft.² instrument panel area
- 24° over the nose visibility

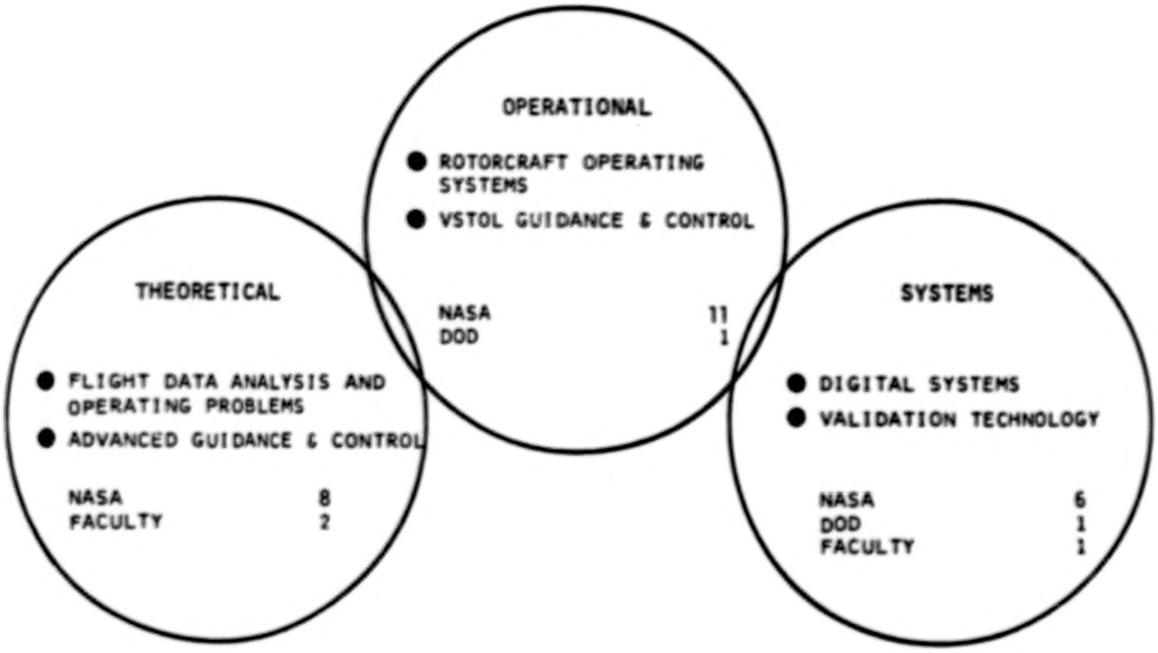
AIRCRAFT GUIDANCE AND NAVIGATION BRANCH

By

Dallas Denery

NASA-Ames Research Center
Moffett Field, California

CAPABILITIES



OPERATIONAL

- ROTORCRAFT OPERATING SYSTEMS
- VSTOL GUIDANCE & CONTROL

NASA	11
DOD	1

THEORETICAL

- FLIGHT DATA ANALYSIS AND OPERATING PROBLEMS
- ADVANCED GUIDANCE & CONTROL

NASA	8
FACULTY	2

SYSTEMS

- DIGITAL SYSTEMS
- VALIDATION TECHNOLOGY

NASA	6
DOD	1
FACULTY	1

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FLIGHT DATA ANALYSIS AND OPERATING PROBLEMS

OBJECTIVE

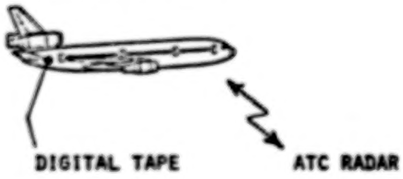
- DEVELOP ADVANCED TECHNIQUES FOR ANALYZING AIRCRAFT FLIGHT RECORDS FOR THE PURPOSE OF IMPROVING AIRCRAFT SAFETY

MAJOR ACTIVITIES

- EXTRACTION OF WIND SHEARS AND TURBULENCE FROM AIRCRAFT RECORDS
- DEVELOPMENT OF TECHNIQUES FOR ANALYZING GENERAL AVIATION ACCIDENTS USING MODE-S ATC RADAR DATA
- ASSISTANCE TO NTSB IN ANALYSIS OF SPECIFIC AIRCRAFT ACCIDENTS

FLIGHT DATA ANALYSIS AND ACCIDENT INVESTIGATION

TURBULENCE ENCOUNTERS

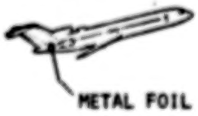


- DC-10, HANNIBAL, MO 4/81
  JETSTREAM INSTABILITY
- DC-10, MORTON, WY 7/82
  MOUNTAIN WAVE

HIGH-ALTITUDE EXECUTIVE JET ACCIDENTS

- LEARJET, FELT, OK 10/81
  KINEMATICS & CONFIGURATION
- LEARJET, SAVANNA, GA 5/82
  KINEMATICS & CONFIGURATION

TAKEOFF ACCIDENTS



- B-737, WASH, D.C. 1/82
  STALL IN ICING
- B-727, NEW ORLEANS, 7/82
  WIND SHEAR AND RAIN

ADVANCED GUIDANCE/ATC RESEARCH

OBJECTIVE

IMPROVE THE EFFECTIVENESS OF CIVIL AND MILITARY AIRCRAFT OPERATIONS THROUGH ADVANCED GUIDANCE AND AIR TRAFFIC CONTROL CONCEPTS

MAJOR ACTIVITIES

DEVELOPMENT OF FUEL EFFICIENT AND 4D GUIDANCE TECHNIQUES

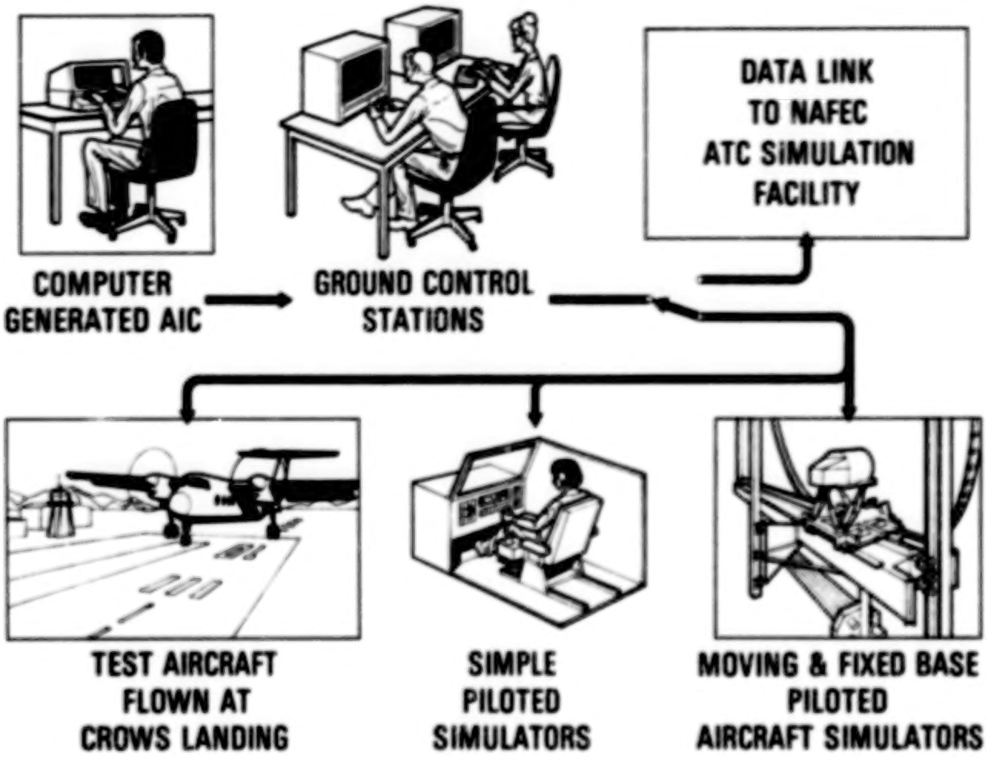
INVESTIGATION OF MODIFICATIONS TO THE ATC SYSTEM TO IMPROVE THE INTERACTION BETWEEN ADVANCED GUIDANCE EQUIPPED AIRCRAFT AND THE ATC

DEVELOPMENT OF AIR-TO-AIR COMBAT GUIDANCE CONCEPTS

SUMMARY OF JOINT NASA/FAA
ADVANCED GUIDANCE/ATC RESEARCH

4D RNAV	1975
FUEL CONSERVATIVE APPROACHES:DELAYED FLAP AND IATA	1977
PROFILE DESCENTS	1977
HELICOPTER IFR	1980
TIME CONTROLLED FUEL CONSERVATIVE GUIDANCE AND ATC MANAGEMENT	1982
TIME CONTROLLED FUEL CONSERVATIVE GUIDANCE AND ATC MANAGEMENT WITH AUTOMATED SCHEDULING (COLOR GRAPHICS)	1983
ADVANCED ON-BOARD GUIDANCE AND AUTOMATED ATC INTERACTION CONCEPTS	1984
OPERATIONAL EVALUATION OF ADVANCED GUIDANCE/ATC CONCEPTS UTILIZING AMES SIMULATORS AND FAATC ATC FACILITY	1984

AIR TRAFFIC CONTROL SIMULATION FACILITY


DATA LINK
TO NAFEC
ATC SIMULATION
FACILITY
COMPUTER
GENERATED AIC
GROUND CONTROL
STATIONS
TEST AIRCRAFT
FLOWN AT
CROWS LANDING
SIMPLE
PILOTED
SIMULATORS
MOVING & FIXED BASE
PILOTED
AIRCRAFT SIMULATORS

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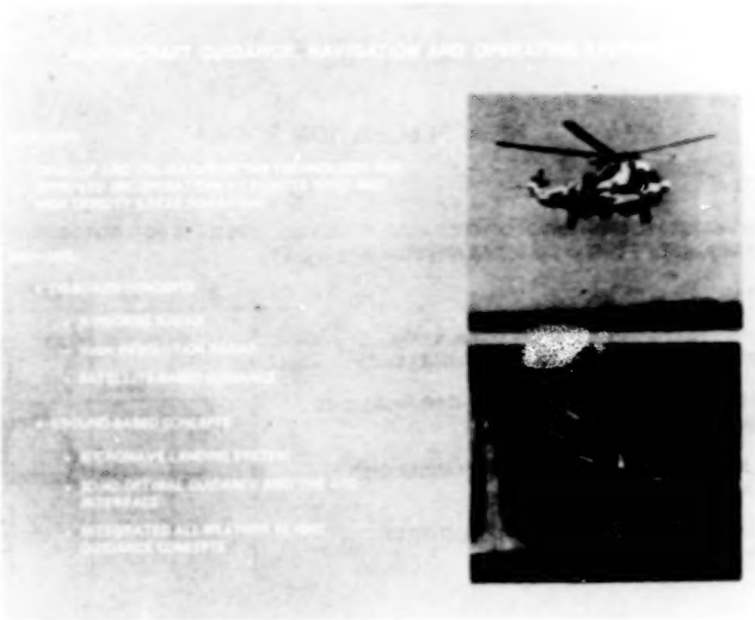


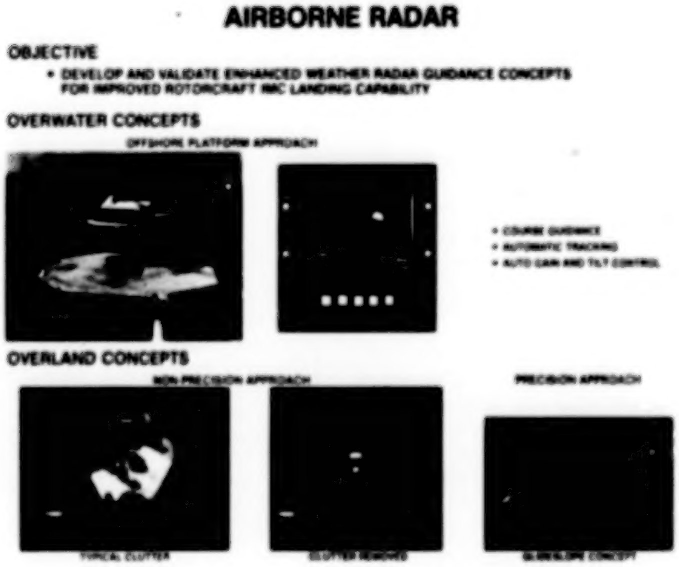
[illegible]CRAFT GUIDANCE, NAVIGATION AND OPERATING [illegible]

[illegible]

[illegible]

[illegible]

- AIRBORNE CONCEPTS
  - AIRBORNE RADAR
  - HIGH RESOLUTION RADAR
  - SATELLITE-BASED GUIDANCE
- GROUND-BASED CONCEPTS
  - MICROWAVE LANDING SYSTEM
  - [illegible] GUIDANCE AND PILOT [illegible] INTERFACE
  - INTEGRATED ALL-WEATHER IMC GUIDANCE CONCEPTS



AIRBORNE RADAR

OBJECTIVE

- DEVELOP AND VALIDATE ENHANCED WEATHER RADAR GUIDANCE CONCEPTS FOR IMPROVED ROTORCRAFT IMC LANDING CAPABILITY

OVERWATER CONCEPTS

OFFSHORE PLATFORM APPROACH

- COURSE GUIDANCE
- AUTOMATIC TRACKING
- AUTO GAIN AND TILT CONTROL

OVERLAND CONCEPTS

NON-PRECISION APPROACH

PRECISION APPROACH

TYPICAL CLUTTER

CLUTTER REMOVED

GLIDESLOPE CONCEPT

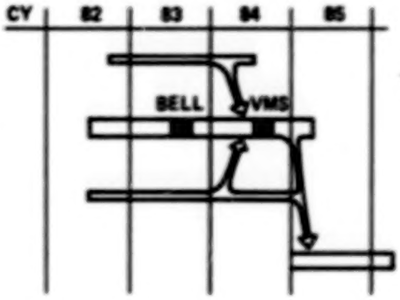
HIGH RESOLUTION RADAR

OBJECTIVE:

- INVESTIGATE HIGH RESOLUTION RADAR GUIDANCE CONCEPTS FOR ROTORCRAFT "ONBOARD" ZERO VISIBILITY LANDING CAPABILITY

PROGRAM:

- HIGH RESOLUTION RADAR SIMULATION METHODOLOGY (HARVEY MUDD COLLEGE)
- CANDIDATE DISPLAY/CONTROL COMBINATIONS (BELL HELICOPTER)
- LANDING GUIDANCE IMAGE ENHANCEMENT (AMA AND UCD)
- RADAR CATEGORY IIIc LANDING SYSTEM PRELIMINARY DESIGN STUDY



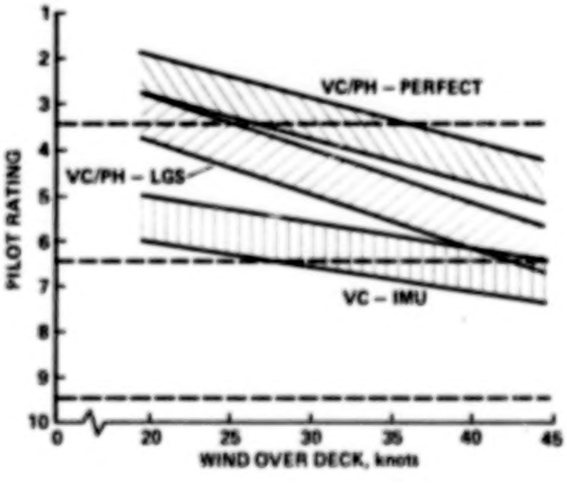
VSTOL GUIDANCE AND CONTROL

OBJECTIVE

- INVESTIGATE GUIDANCE, NAVIGATION AND CONTROL CONCEPTS FOR POWERED LIFT AIRCRAFT

MAJOR ACTIVITIES

- DEVELOP PRECISION LANDING GUIDANCE CONTROL AND DISPLAY CONCEPTS FOR POWERED LIFT A/C
- DEVELOP EMG CONCEPTS FOR POWERED LIFT A/C
- EVAL OPERATIONAL USE OF EMG FOR:
  - 4D GUIDANCE
  - SHIPBOARD LANDING
  - CRATERED RUNWAY LANDING



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DEMONSTRATION ADVANCED AVIONICS SYSTEM

OBJECTIVE

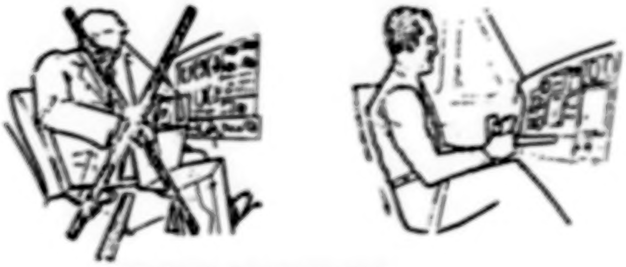
PROVIDE THE INFORMATION REQUIRED FOR THE DESIGN OF FULLY INTEGRATED AVIONICS SUITABLE FOR GENERAL AVIATION IN THE 1980's AND BEYOND.

ISSUES

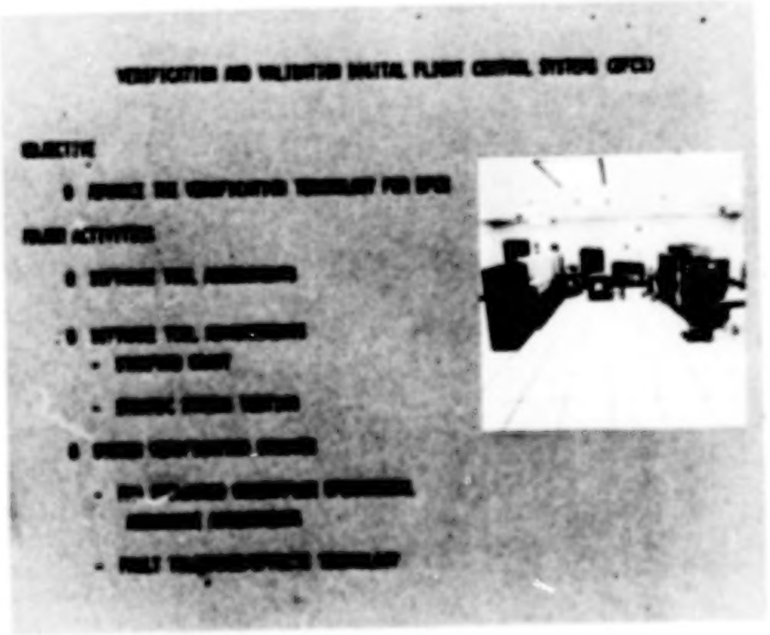
PILOT SYSTEM INTERFACE
  - O CAPABILITY
  - O SAFETY

ARCHITECTURAL DESIGN
  - O RELIABILITY
  - O MAINTAINABILITY
  - O MODULARITY
  - O COST

DAAS FUNCTIONAL CAPABILITIES



- GUIDANCE AND NAVIGATION
- FLIGHT CONTROLS
- FLIGHT STATUS
- COMPUTER ASSISTED HANDBOOK COMPUTATIONS
- MONITORING AND WARNING
- DATA LINK
- COMPUTER ASSISTED MAINTENANCE
- NORMAL AND EMERGENCY CHECKLISTS
- SIMULATION



VERIFICATION AND VALIDATION DIGITAL FLIGHT CONTROL SYSTEMS (DFCS)

OBJECTIVE

- ADVANCE THE VERIFICATION TECHNOLOGY FOR DFCS

MAJOR ACTIVITIES

omit to
END

APPENDIX C

MAN MACHINE INTERFACE REQUIREMENTS COMMITTEE

CHAIRMAN: DR. R. W. REMINGTON, Ph.D.

CO-CHAIRMAN: DR. E. L. WIENER, Ph.D.

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MAN-MACHINE INTERFACE REQUIREMENTS COMMITTEE

CHAIRPERSON: Dr. Roger W. Remington, Ph.D.

CO-CHAIRPERSON: Dr. Earl L. Wiener, Ph.D.

COMMITTEE MEMBERS	AFFILIATION
Gerry Armstrong	Edwards Air Force Base
Richard Armstrong	U.S. Army Human Eng. Lab.
Bob Barney	IBM-Federal Systems Div.
Colleen Burington	Hughes Helicopter, Inc.
Ye-yeen Chu	Perceptronics
Warren Clement	Systems Technology, Inc.
Clay Coler	NASA-Ames Res. Ctr.
Ren Curry	NASA-Ames Res. Ctr.
James Gracia	Harris Corp.
Al Godwin	General Dynamics
Jim Hartzell	NASA-Ames Res. Ctr.
Steven Hill, Maj. USMC	Camp Pendleton
Edward Huff	NASA-Ames Res. Ctr.
Richard Jagacinski	Ohio State University
Azad Madni	Perceptronics
Joy Mountford	Honeywell, Inc.
Bill Mulley	Naval Air Development Ctr.
Jim Phillips	NASA-Ames Res. Ctr.
Stan Roscoe	New Mexico State Univ.
Skip W. Stagg	Hughes Helicopter, Inc.
Jerry Wald	Honeywell, Inc.
Andrew Watson	NASA-Ames Res. Ctr.
Bob Wherry	Analytics
David Young	UTC/Sikorsky Aircraft

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APPENDIX D

WORKSHOP AGENDA AND PARTICPANTS

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TECHNICAL WORKSHOP

Advanced Helicopter Cockpit Design Concepts

July 26 - 28, 1983

Sponsored by:

Ames Helicopter/VTOL Human Factors Office
and the
Aircraft Guidance and Navigation Branch of the
National Aeronautics and Space Administration, Ames Research Center

Chairman: J. C. Hemingway
Co-Chairman: G. P. Callas

AGENDA

TUESDAY, 26 July 1983

FORUM SESSION

0830	C. A. Syvertson	Welcome
0840	I. C. Statler	Opening Remarks
0850	R. D. Showman	Super-Augmented Rotorcraft Program
0905	D. G. Denery	ARC Guidance & Navigation Programs and Plans
0915	E. M. Huff	ARC Helicopter Human Factors Programs and Plans
0935	COFFEE BREAK	
0945	MAJ G. Philips, US Army/ MAJ Steven Hill, USMC	Army/Marine Helicopter Missions
1005	LT R. M. Morrison	Civil Law Enforcement Missions
1025	D. A. Young	Maritime SAR Missions
1045	G. E. Tucker	NOE/HMD Missions
1105	E. J. Hartzell	LHX/ARTI Missions
1130	LUNCH	

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GENERAL AGENDA (continued)

1300	R. B. Huntoon	Recent Experiences with Integrated Digital Avionics
1330	T. Drennen/D. Strother	Experiences with Integrated Digital Avionics
1400	C. Richardson	Experiences with Integrated Digital Avionics
1430	W. Mulley	Advanced Avionics Systems Integration
1450	COFFEE BREAK	
1500	E. Wiener	Cockpit Automation
1530	A. Madni	Intelligent Interface
1600	H. Snyder	Man-Machine Systems Integration
1630	R. J. Wherry	Cockpit Design & Validation
1700	Adjourn	

WEDNESDAY, 27 July 1983

COMMITTEE MEETINGS

0830 Convene Committees

*Operational Requirements - System Concepts
Chairmen: J. Voorhees, H. Snyder

*Avionics Technology - System Concepts
Chairmen: J. Bull, D. Lammers

*Man-Machine Interface Requirements - Advanced Technology
Chairmen: R. Remington, E. Wiener

1200 LUNCH

1330 Reconvene Committees

1700 Adjourn Committees

1900 Banquet - Hyatt Palo Alto
Dinner Speaker: Stan Roscoe - "Faith in the Visual World"

GENERAL AGENDA (Continued)

THURSDAY, 28 July 1983

COMMITTEE REPORTS

Committee Chairman: J. Seeman

0830	Operational Requirements - System Concepts
0915	Avionics Technology - System Concepts
1000	COFFEE BREAK
1015	Man-Machine Interface Requirements - Advanced Technology
1100	Panel Discussion with open questions
1200	Wrap-up
1300	Ames Tour

END

DATE

FILMED

MAR 1 1985

CAUTION ALERTS AND WARNINGS

DC-8	172
B-707	188
DC-10	418
B-747	455

QUESTION: WHAT IS NEEDED IN WARNING AND ALERTING?

- 0 A FRESH, COCKPIT-WIDE LOOK AT THE PROBLEM
- 0 A METHOD FOR INCORPORATING NEW SYSTEMS INTO ALREADY STABILIZED COCKPITS (E.G. T-CAS)
- 0 A NEW "LAW OF PARSIMONY"
- 0 UTILIZATION OF NEW DISPLAY TECHNOLOGIES

MAJOR PROBLEM AREAS

- 0 INPUT METHODS
- 0 OUTPUT (DISPLAY) METHODS
- 0 TRAINING

C-3

INPUT

0 IS THE KEYBOARD THE WAY TO GO? IS VOICE?

0 OPERATOR-COMPUTER DIALOG DESIGN

0 WHAT TO DO WHEN THINGS GO WRONG

  LOCKUP AND REENTRY
  THE YELLOW BUTTON
  BACKUP AVAILABILITY

QUESTION: COULD ONE MISPLACED COMMA RESULT IN AN AIRCRAFT ACCIDENT OR ABORTED MISSION?

OUTPUT

0 INFORMATION GLUT AND COGNITIVE OVERLOAD

0 WHAT TO DISPLAY, AND HOW BEST TO FORMAT IT

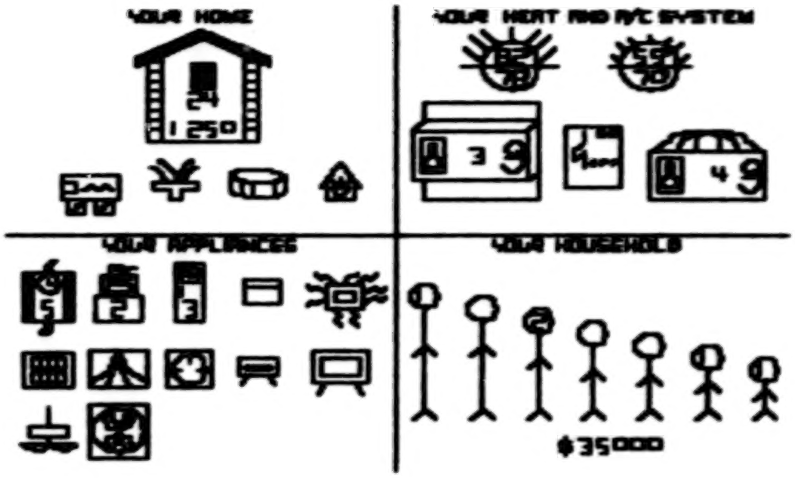
0 NON-TRADITIONAL METHODS AND DISPLAYS

TRAINING

- BEYOND THE STATIC CLASSROOM
- FULL-TASK SIMULATION TOO EXPENSIVE
- PAPER TRAINERS TOO LIMITED
- NON-TRADITIONAL APPROACHES NEEDED
  CAI, DIALOG SYSTEMS, HOME TERMINALS, VIDEO DISKS, INTERACTIVE CABLE, ETC.

WHERE DO WE GO FROM HERE?

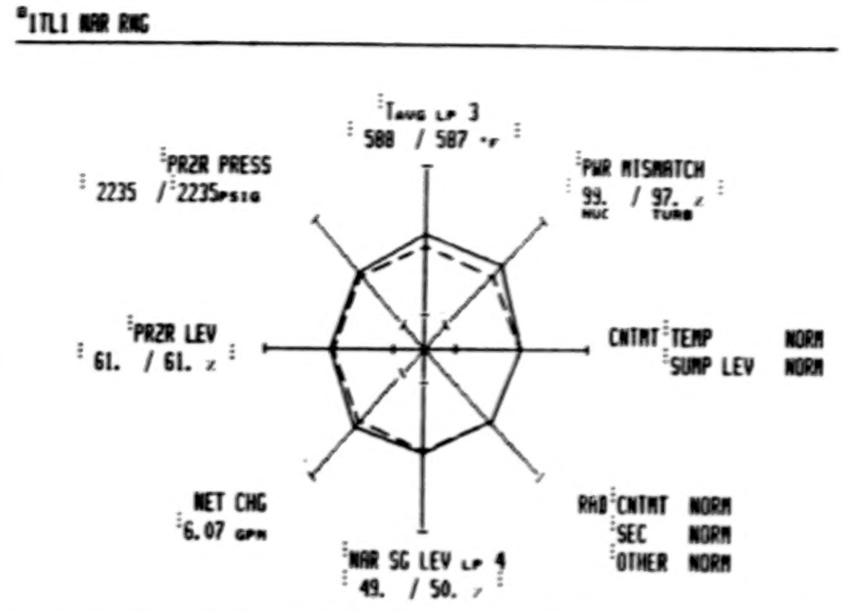
- INPUT - REDUCTION OF KEYBOARDS (HOW?)
- OUTPUT - ENHANCED DISPLAYS, ECONOMICAL DISPLAYS
- DECISION SUPPORT SYSTEMS
- ARTIFICIAL INTELLIGENCE


YOUR HOME
1250
YOUR HEAT AND A/C SYSTEM
YOUR APPLIANCES
YOUR HOUSEHOLD
$35000

SLIDE 1

Figure 2. *Facial expressions created by different combinations of mouth, eyebrows, and pupils as the irrelevant features.*

SLIDE 2



1TL1 NAR RNG
TAVG LP 3
588 / 587 °F
PRZR PRESS
2235 / 2235PSIG
PWR MISMATCH
99. / 97. %
NUC TURB
PRZR LEV
61. / 61. %
CNTMT TEMP NORM
SUMP LEV NORM
NET CHG
6.07 GPM
RAD CNTMT NORM
SEC NORM
OTHER NORM
NAR SG LEV LP 4
49. / 50. %

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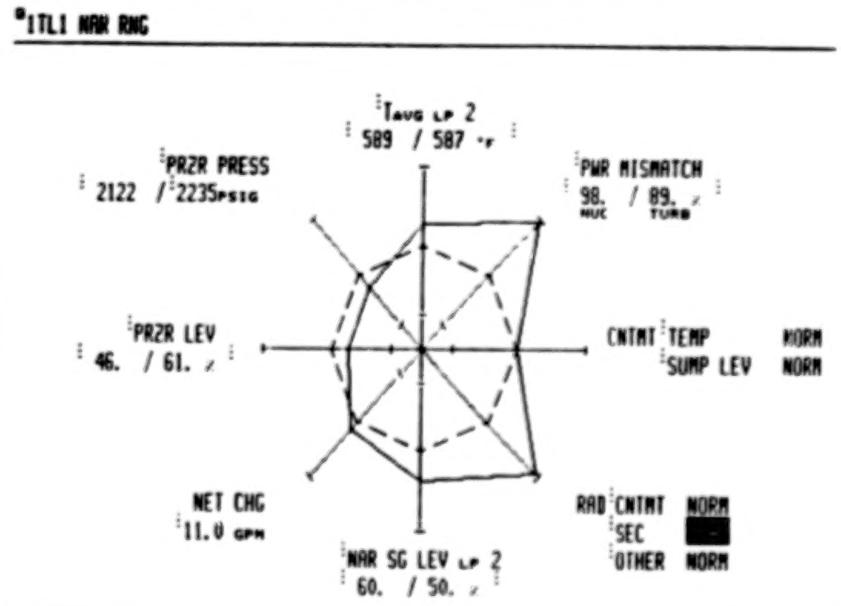
FIGURE 1



1TL1 NAR RNG
TAVG LP 2
589 / 587 °F
PRZR PRESS
2122 / 2235PSIG
PWR MISMATCH
98. / 89. %
NUC TURB
PRZR LEV
46. / 61. %
CNTMT TEMP NORM
SUMP LEV NORM
NET CHG
11.0 GPM
RAD CNTMT NORM
SEC
OTHER NORM
NAR SG LEV LP 2
60. / 50. %

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FIGURE 2

SLIDE 3

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ORIGINAL PAGE IS
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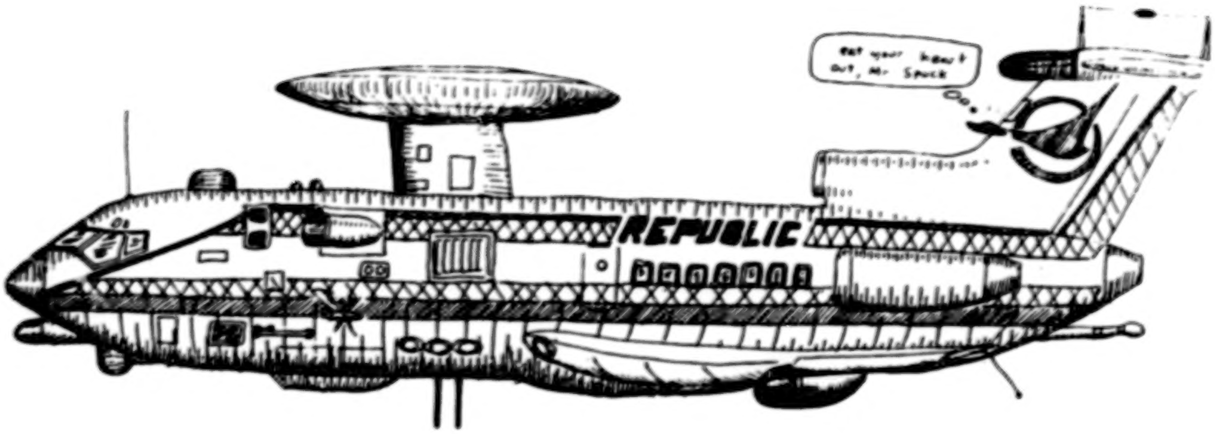
eat your heart out, Mr Spock
REPUBLIC

SLIDE 4

N85 14820

INTELLIGENT INTERFACES
FOR TACTICAL AIRBORNE PLATFORMS

By

Azad Madni

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BACKGROUND

PERCEPTRONICS

- Enhanced capabilities of tactical airborne platforms have resulted in:
  - increased number of aircrew tasks
  - greater task complexity
  - increased time-stress in task performance
- Function automation and onboard decision aids have become a necessity
- Automation and decision aiding do not necessarily guarantee reduction in aircrew workload or enhanced aircrew performance
- "Embedded intelligence" in the aircrew-vehicle interface (AVI) can help alleviate aircrew workload and enhance aircrew performance by:
  - optimizing the exchange of information between the aircrew and the onboard automation
  - adaptively allocating functions between aircrew and automation in response to situational demands

THE INTELLIGENT INTERFACE (I^2)

PERCEPTRONICS

- A knowledgeable mediator between the aircrew and the onboard automation that maximizes aircrew-vehicle performance across the spectrum of tactical situations for a given degree of onboard machine intelligence and a given level of aircrew capability*

*Aircrew Capability = Aircrew Capacity + Aircrew Training

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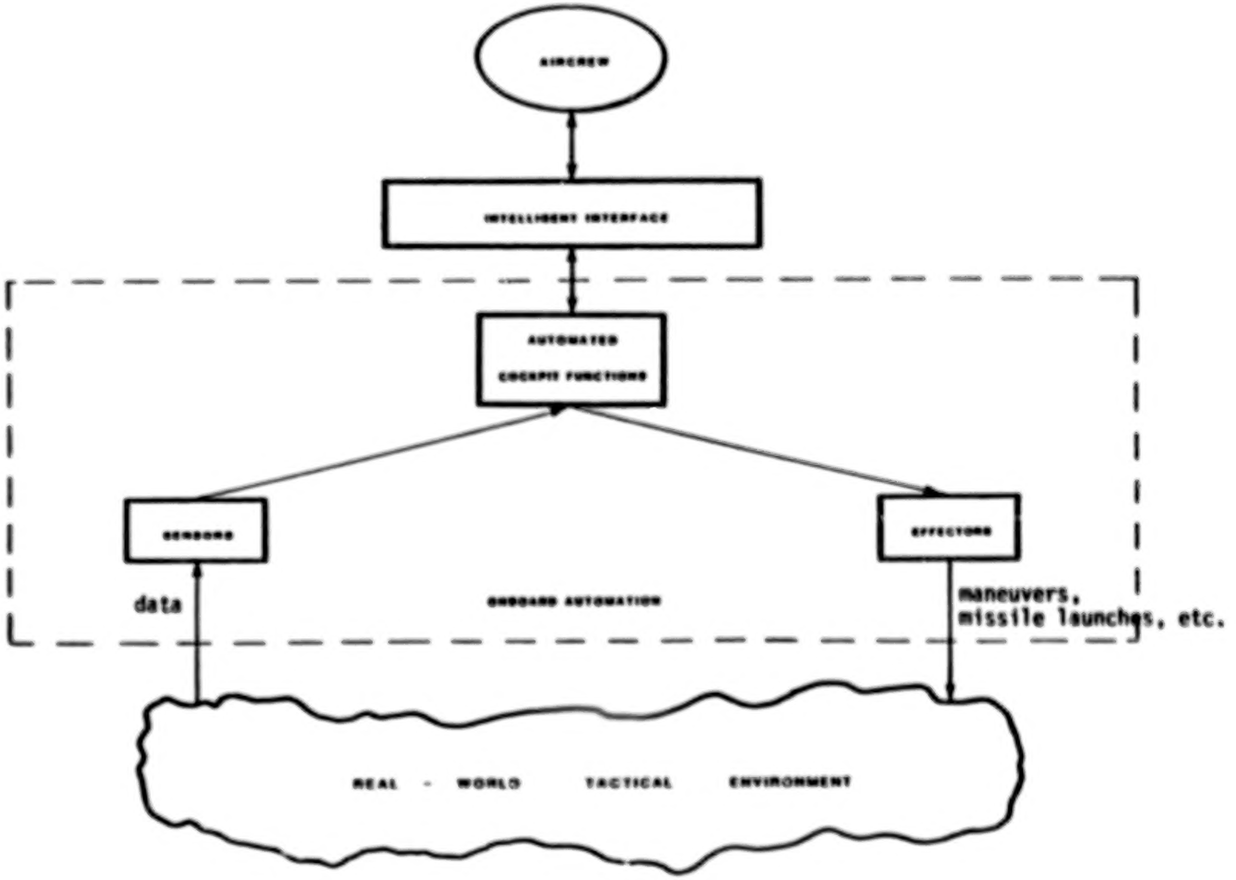
GENERIC MODEL OF THE AIRCREW-VEHICLE SYSTEM


AIRCREW
INTELLIGENT INTERFACE
AUTOMATED
COCKPIT FUNCTIONS
SENSORS
EFFECTORS
data
ONBOARD AUTOMATION
maneuvers,
missile launches, etc.
REAL - WORLD TACTICAL ENVIRONMENT

INTELLIGENT INTERFACE ISSUES

PERCEPTRONICS

- . HOW TO ENSURE THAT THE AIRCREW CAN COPE WITH THE INFORMATION INFLUX
- . HOW TO PRESENT/PORTRAY BOTH SITUATIONAL AND INTERNAL STATUS INFORMATION
- . HOW TO ALLOCATE FUNCTIONS BETWEEN THE AIRCREW AND THE ONBOARD AUTOMATION
- . HOW TO EXPLAIN REASONING PROCESSES EMPLOYED BY ONBOARD INTELLIGENCE TO THE AIRCREW
- . HOW TO TAILOR SITUATIONAL INFORMATION TO THE COGNITIVE DEMANDS OF THE OPERATOR
- . HOW TO COMMUNICATE HIGH PRIORITY INFORMATION TO THE AIRCREW
- . HOW TO FACILITATE AIRCREW'S TASK IN INFUENCING/CONTROLLING SPECIFIC SUBSYSTEMS OF THE VEHICLE VIA THE ONBOARD AUTOMATION FUNCTIONS
- . HOW TO ENHANCE OPERATORS CAPABILITY IN SUPERVISING/DIRECTING ACTIVITIES OF THE VARIOUS SUBSYSTEMS VIA THE ONBOARD AUTOMATION

EXAMPLES OF I^2 FEATURES

PERCEPTRONICS

- . "EMBEDDED" AIRCREW INFORMATION PREFERENCE MODELS
- . SYMBOLIC MULTI-ATTRIBUTE PORTRAYAL OF OWN SHIP FLIGHT INFORMATION
- . TASK-ORIENTED SUPERVISORY COMMAND LANGUAGE
- . INFORMATION PACING/SUMMARIZATION HEURISTICS
- . TACTICAL SITUATION PORTRAYAL IN AIRCREW-COMPATIBLE SYMBOLOGY, LEVEL OF ABSTRACTION AND FORMAT
- . MODALITY-OPTIMIZED PROMPT/DISPLAY SELECTION
- . SITUATION-ADAPTIVE AIRCREW-AUTOMATION FUNCTION ALLOCATION
- . PERFORMANCE MONITORING/FEEDBACK

INFORMATION MANAGEMENT

PERCEPTRONICS

- Information Selection Aid
  - ADAPTIVELY* PRIORITIZING INFORMATION IN ACCORD WITH PREVAILING AIRCREW NEEDS/PREFERENCE
- Information Pacing Aid
  - PACING INFORMATION IN ACCORD WITH AIRCREW COGNITIVE CONSTRAINTS AND SITUATIONAL DEMANDS
- Information Summarization Aid
  - SUMMARIZING INFORMATION BASED ON INFORMATION VOLUME AND NEED FOR TIMELY AIRCREW ACTION

*ADAPT TO AIRCREW NEEDS, TASK DEMANDS, ENVIRONMENTAL CONSTRAINTS

COMMAND/QUERY LANGUAGE

PERCEPTRONICS

- Natural/high level
- Incomplete/imprecise command handling
- Aircrew-oriented vocabulary

FUNCTION ALLOCATION

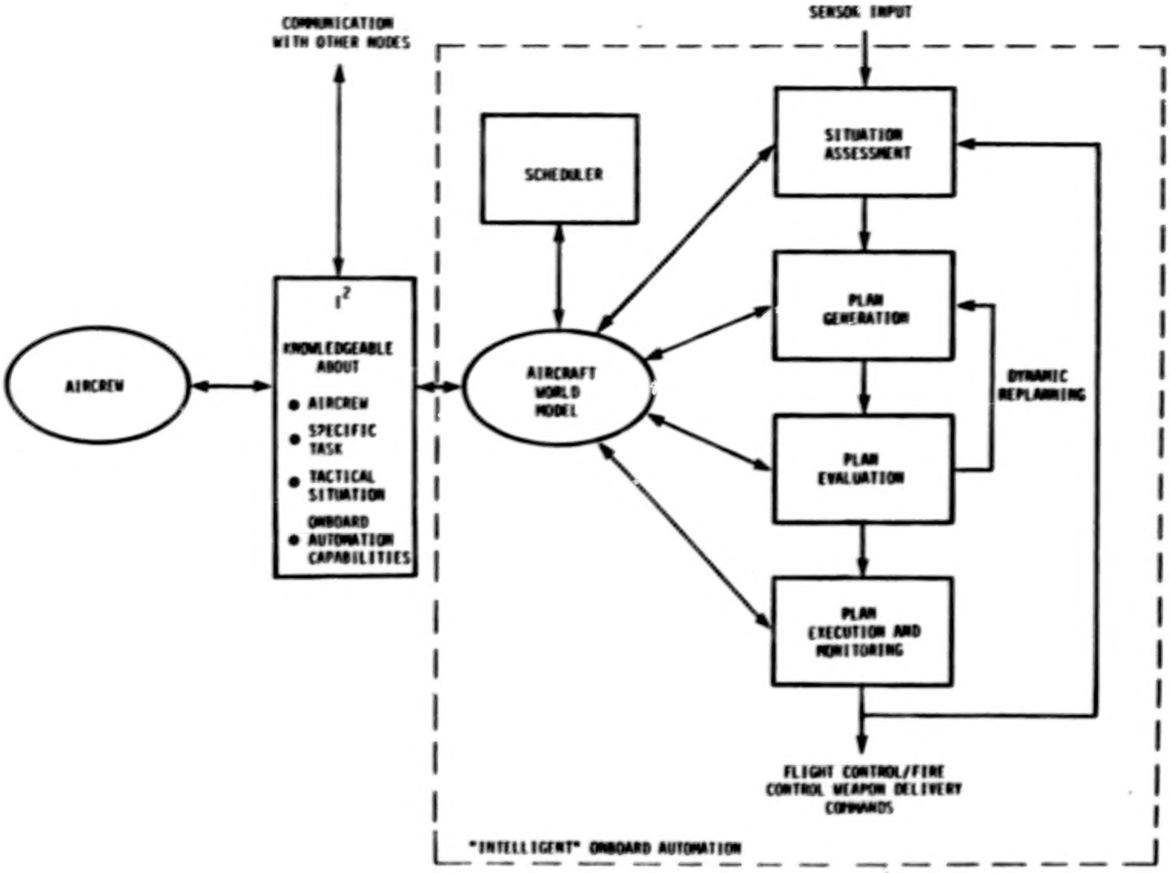
PERCEPTRONICS

- MAN WORKING WITH MACHINE
- KEY A PRIORI CONSIDERATIONS
  - OPERATOR'S CAPABILITIES AND LIMITATIONS
  - AUTOMATION'S CAPABILITIES AND LIMITATIONS
  - REGULATIONS AND DOCTRINES
  - ECONOMIC FEASIBILITY
  - SYSTEM PERFORMANCE REQUIREMENTS
  - IMPLEMENTATION FEASIBILITY
  - SAFETY
- REALTIME CONSIDERATIONS (SITUATION-ADAPTIVE)
  - ENVIRONMENTAL CONSTRAINTS
  - UNEXPECTED EVENTS
  - UTILITY AND JOB SATISFACTION
  - TEMPORAL AVAILABILITY OF OPERATOR/AUTOMATION
- MANUAL BACKUP WHERE PRACTICABLE

FEEDBACK

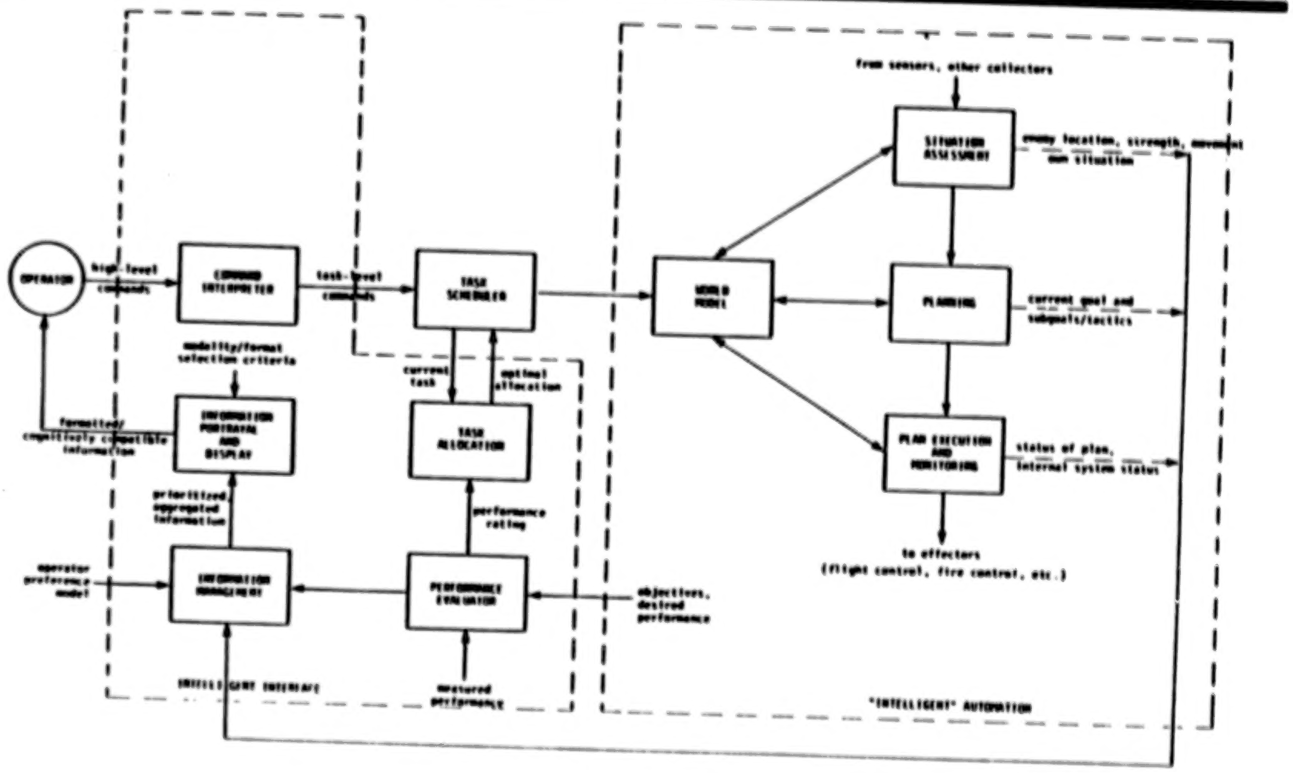
PERCEPTRONICS

- COMPATIBLE WITH COGNITIVE DEMANDS OF AIRCREW
- VARIABLE MODALITY PROMPTS
- MULTIPLE LEVELS OF ABSTRACTION
- MULTIPLE MODES (TEXTUAL/GRAPHICS)
- SITUATION-DRIVEN (NORMAL/CONTINGENCY)


COMMUNICATION WITH OTHER NODES
SENSOR INPUT
SCHEDULER
SITUATION ASSESSMENT
PLAN GENERATION
DYNAMIC REPLANNING
PLAN EVALUATION
PLAN EXECUTION AND MONITORING
AIRCREW
I²
KNOWLEDGEABLE ABOUT
• AIRCREW
• SPECIFIC TASK
• TACTICAL SITUATION
• ONBOARD AUTOMATION CAPABILITIES
AIRCRAFT WORLD MODEL
FLIGHT CONTROL/FIRE CONTROL WEAPON DELIVERY COMMANDS
"INTELLIGENT" ONBOARD AUTOMATION

THE INTELLIGENT INTERFACE TO AUTOMATED ONBOARD FUNCTIONS

PERCEPTRONICS


OPERATOR
high-level commands
COMMAND INTERPRETER
task-level commands
TASK SCHEDULER
modality/format selection criteria
formatted/ cognitively compatible information
INFORMATION PORTRAYAL AND DISPLAY
current task
optimal allocation
TASK ALLOCATION
prioritized, aggregated information
performance rating
operator preference model
INFORMATION MANAGEMENT
PERFORMANCE EVALUATOR
objectives, desired performance
INTELLIGENT INTERFACE
measured performance
from sensors, other collectors
SITUATION ASSESSMENT
enemy location, strength, movement
own situation
WORLD MODEL
PLANNING
current goal and subgoals/tactics
PLAN EXECUTION AND MONITORING
status of plan, internal system status
to effectors
(flight control, fire control, etc.)
"INTELLIGENT" AUTOMATION

. KNOWLEDGE BASE MANAGEMENT AND RETRIEVAL OF:

  - AERIAL DATA
  - ORDER OF BATTLE
  - SYSTEM STATUS
  - RULES OF ENGAGEMENT

. CONTROL AND MONITORING OF:

  - SUBSYSTEM STATUS
  - MUNITIONS INVENTORY
  - PLAN EXECUTION
  - SPATIAL LOCATION AND CURRENT COURSE

. DYNAMIC FUNCTION ALLOCATION IN:

  - ENVIRONMENT SENSING
  - EVENT MONITORING
  - WEAPON SELECTION/FIRE CONTROL
  - TACTICAL PLANNING
  - SENSOR DATA FUSION/INTERPRETATION

N85 14821

HUMAN FACTORS OF VISUAL DISPLAYS

Harry L. Snyder, Ph.D.

Virginia Polytechnic Institute and State University
Blackburg, Virginia

INTRODUCTION

Other speakers at this symposium have addressed or will address cockpit integration or voice technology, and these important subjects certainly should command our attention. At the same time, we anticipate the placement of a variety of visual displays in the cockpit in somewhat conventional fashion, either as fundamental instruments or as backup instruments. There is a large database on human factors in display design. While many persons in attendance at this workshop are quite expert in this area as well, it is critical that we do not forget some of the fundamentals which are pertinent to interpretation of information in rapid and accurate fashion by the crew. This paper will touch upon some of the fundamental issues which still remain to be addressed, as current research is largely inadequate for all our application purposes. Where possible, data will be presented to illustrate the importance of some of these topics.

LUMINANCE, LUMINANCE RANGE, AND CONTRAST

It is often considered important that displays be of a certain luminance in order to achieve adequate intelligibility. Research shows, however, that the overall luminance is not nearly as critical as is the luminance contrast. While many specifications call for a minimum contrast ratio of 1.4:1, a contrast ratio of 9:1 is actually preferred and leads to better performance. However, all weather and night operations require a large dynamic range to achieve this contrast ratio. Problems exist at the upper illumination end because of direct sunlight (often of the intensity of 100,000 lux) and glare; at the lower illumination end, problems exist due to transient adaptation of the visual system.

It is usually considered appropriate to overcome high illumination conditions with very high luminance and high contrast displays. In many situations, glare reducing filters are added to improve the contrast under such illumination conditions. Popular filters include circular polarizers, one-quarter wave filters, spectrally notched filters, and mesh filters. In fact, it can be demonstrated that each of these filters causes some degradation of the image at certain off-axis angles. It would be well to consider using color contrast to supplement luminance contrast, as will be discussed sequently in this paper.

At the low end of illumination, we have two difficulties, one caused by the hardware and the other by the visual system. As the luminance of a typical display (e.g., CRT) is reduced, there tends to be an increase in the nonuniformity of the display. That is, certain parts of the display will go toward black faster than will other parts of the display, thereby leading to a much more noisy display and one which may in fact eliminate information critical to the crew member. The second, transient adaptation, problem is simply the result of the visual system requiring some amount of time to adapt to changes in overall luminance of the visual field. It has been demonstrated that adaptation changes over a factor of 10 or more will reduce visual acuity by two or three times, and that greater adaptation shifts will further reduce visual acuity as well as cause greater delays in adaptation to the new luminance level. This loss of sensitivity occurs in either direction: dark to light or light to dark. Thus, adapting from the dark outside, as in nighttime flying, to the somewhat more luminous displays causes both the problem of adaptation to the brighter display as well as the reverse problem of dark adaptation going from the display back to the outside.

It is clear from the above that displays must require a broad dynamic range for high legibility under high illumination conditions without being unnecessarily bright. Similarly, such displays require greater uniformity under low luminance conditions, and the nature of this type of control has yet to be explored satisfactorily for many applications.

UNIFORMITY

As mentioned above, there is currently no proven or agreed upon standard for either large area or small area nonuniformity of visual displays. While this is particularly critical at low luminance levels, it is also important for high luminance levels. Furthermore, with the current types of flat panel displays available, it is often the case that individual cells or lines will be turned either "on" or "off" inappropriately. Recent research in our laboratory has shown that there is a significant reduction in reading performance from a display which has as few as two percent of the cells inappropriately illuminated. This subject area needs further investigation to set standards for display acceptance and quality control.

IMAGE QUALITY

Speed and accuracy of display interpretation are significantly affected by general image quality, although system/display specifications used in current procurements still use archaic specifications which are irrelevant to overall image quality and user performance. Over the last fifteen years, there has been a large amount of research on image quality, and several metrics have been shown to be very useful. One such metric is the modulation transfer function area (MTFA), which is simply the integral of the power between the visual threshold function and the modulation transfer function of the display. High correlations have been obtained between MTFA and several types of user performance, as illustrated in Figures 1 and 2.

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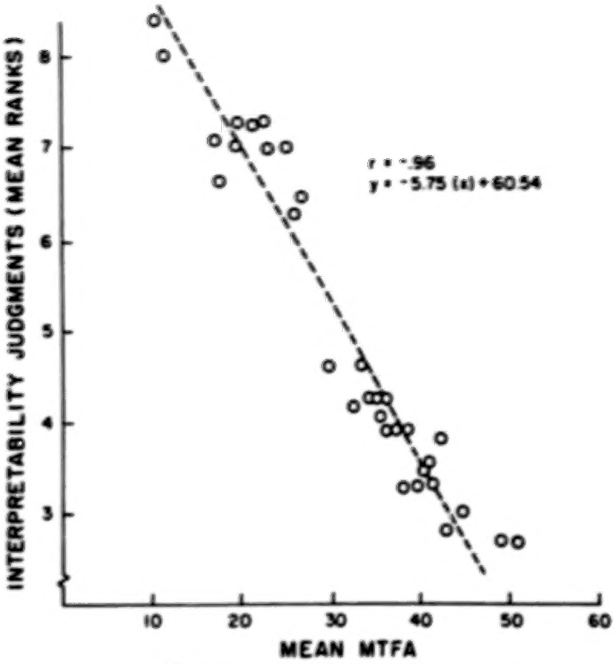


Figure 1. Correlation between image quality and subjective judgment of quality.

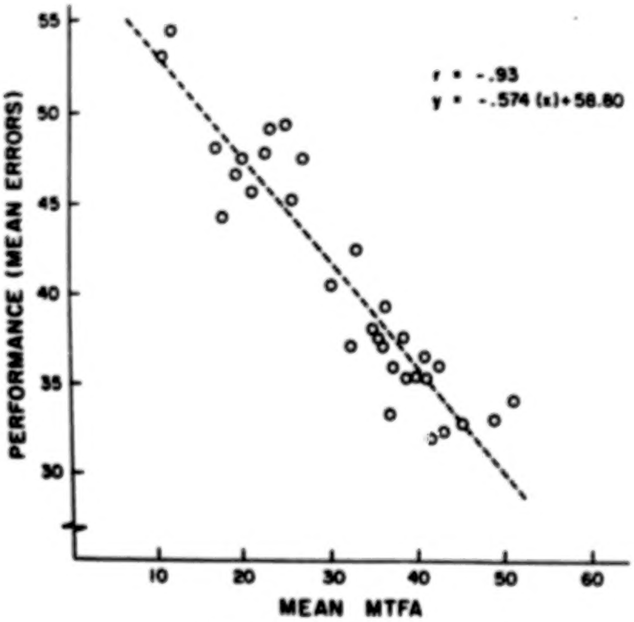
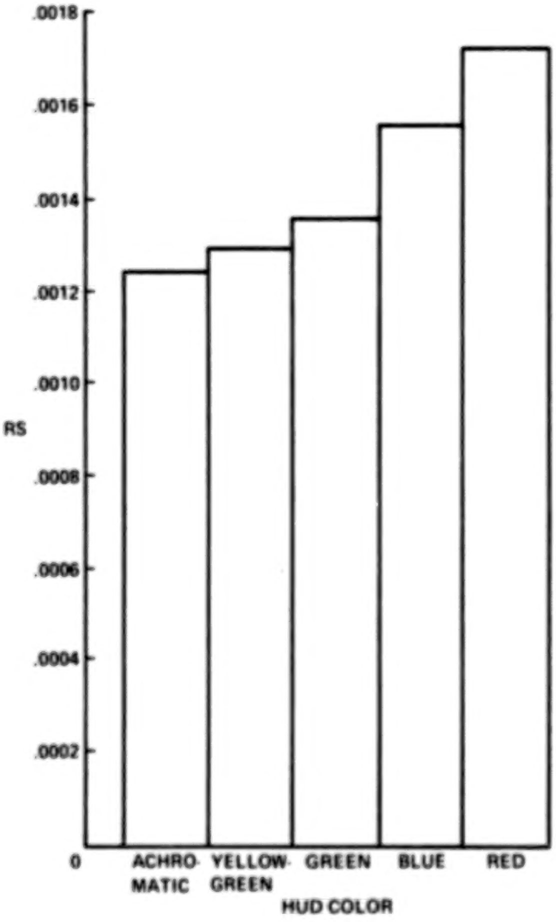


Figure 2. Correlation between image quality and measured observer performance.

COLOR CONTRAST AND LUMINANCE CONTRAST

Our color measurement system (e.g., CIE spaces) have been designed to permit reliable replication of physical colors. Unfortunately, they have often been considered to be indices of psychophysical distances or perceptual spaces. When used as such, they provide some suggestions as to relative importances of distances within the color domain, but these measures do not form good design criteria as there is simply no basis for using these data in visual performance conditions. What is needed, of course, is a good measure of perceptability of color differences, particularly when such color differences are combined with luminance differences. That is, a uniform colorspace which incorporates both chromatic and luminous differences is required for display tradeoff studies. Recent research funded by the Office of Naval Research in our laboratory has produced a measure which appears to be meaningful and valid. While it is beyond the intent of this paper to discuss such metrics, one interesting result has been obtained. Specifically, it is quite clear that color contrast is much more effective than is luminance contrast under most conditions. Using a simulated head-up display (HUD), it was shown that colored displays were much more effective against real world backgrounds than were achromatic (white) displays, which is the most typical display currently in use. As illustrated in Figure 3,



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the red HUD was more effective than was blue or green. The two least effective colors were the white and yellow-green, the two most common transparent display colors. While it is obvious that introducing red displays into the cockpit causes certain sterotypical problems, careful review of overall cockpit design suggests that such integration is possible, meaningful, and likely to be very beneficial. In addition, the retention of dark adaptation permitted by a RED head-up display is particularly attractive.

DOT MATRIX FONTS

One can find as many different letter styles (fonts) as one finds pieces of display hardware. While there have been standardized fonts for high legibility with stroke characters, matrix addressed displays have not yet yielded to standardization of character styles or formats. Research on this subject has indicated that there are considerable differences in legibility of various fonts, and that (more critically) the legibility differences among these fonts are influenced significantly by the number of dots making up the character. Figure 4

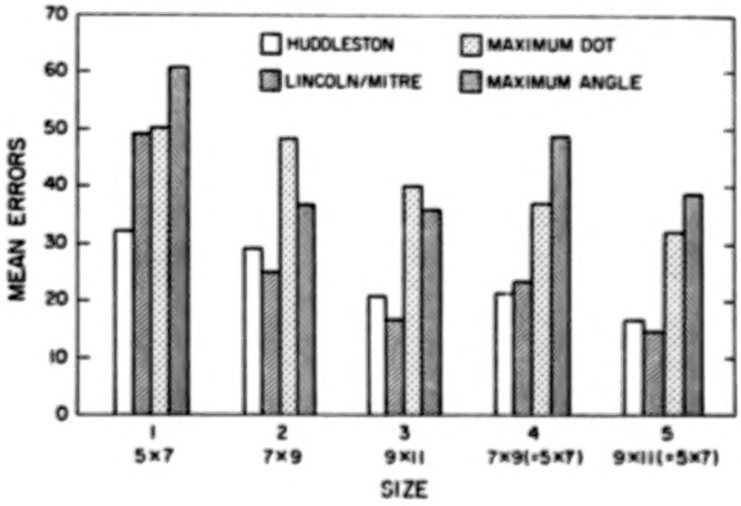


Figure 4. Legibility errors as a function of dot-matrix size and character font.

illustrates one such result, and indicates that further research and standardization is required.

SUMMARY

There is no question that many of the advanced technologies dealing with voice input and output, cockpit integration, display integration, and others are urgent subjects and require diligent research for the next generation of helicopters. At the same time, there are some fundamentals regarding visual displays which cannot and should not be disregarded. We have seen too often the effects of such disregard of these types of principles, as indicated by recent issues in nuclear power control rooms, office video display terminals,certain general aviation nonconventional panel layouts, and the inability of certain night visual systems to provide reasonable crew performance even though they meet current specifications. As Winston Churchill once suggested, disregard of the lessons of history often causes repetition of those lessons. I submit that we still have some basic research to do in visual display for helicopter cockpits and that this research and understanding should underlie and supplement some of the other topics being discussed at this workshop.

N85 14822

CREWSTATION DESIGN & VALIDATION

Robert J. Wherry, Jr., PhD

Private Consultant
Chalfont, Pennsylvania

SUMMARY

The CAR, CUBITS, GROUP, ABBREV, VRAS, and HOS programs are all products of the Navy's Human Factors Engineering Technology Development program. They have been emphasized here for several reasons. First, they are all techniques with which I am intimately familiar and can, therefore, speak with some authority. Secondly, they are representative of the type of technology which was previously indicated as necessary to move crewstation design and validation to a higher level of maturity, one which takes cognizance of the multivariate nature of the problems faced by the crewstation designer and has a far less dependence of the whims of personal or subjective opinion. Finally, these techniques have been emphasized because one too often hears that we don't know how to design and validate crewstations when the truth of the matter is that a great proportion of engineers involved in crewstation design are unaware of the availability of the new technology.

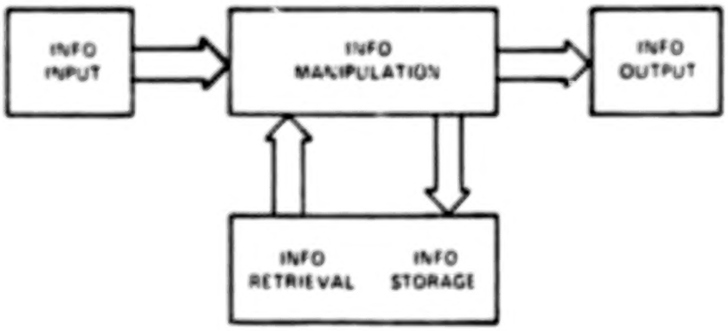
I would not claim that any of the techniques discussed are complete or could not be improved. Indeed, I would claim quite the opposite; much work remains to be done and there will always be some room for improvement. We can, however, see in these techniques a beginning of coming to grips with the central problem in crewstation design, that of optimizing the exchange of information between the human and machine components of a system.

INFO THRUPUT

Processes which are required of components to be able to handle information are inputting, manipulating, storage and retrieval, and outputting. The structure of the mechanisms which permit these processes to occur in humans and machines are quite different but this does not mean that man and machine cannot perform similar functions. Artificial intelligence is primarily concerned with the design of software structures within the two middle boxes which will permit computers to emulate the cognitive functions of humans.

Crewstation design is primarily concerned with the other two boxes (information inputting and outputting) or the exchange of information between humans and machines.

Information, whenever it is exchanged between two components must be coded in some fashion before being transmitted elsewhere. Advanced visual display concerns center on problems of optimal coding (or formatting) of information such that the human can rapidly and accurately input certain types of required information incoded visually. Voice interactive systems, on the other hand, are concerned with the exchange of information between humans and machines when the information has been coded into verbalized utterances. Such systems require sufficiently complex machine components for the manipulation of information received and recalled from memory that these systems are themselves examples of artificial intelligence.



NEED FOR INFORMATION EXCHANGE

Information exchanges are required because humans and machines are allocated different functions and neither can function in an optimal manner without getting appropriate inputs from other components. The speed and accuracy with which information can be exchanged between the human and machine components, therefore, has significant impact on how optimally the system, as a whole, can accomplish its mission.

STEMS FROM:

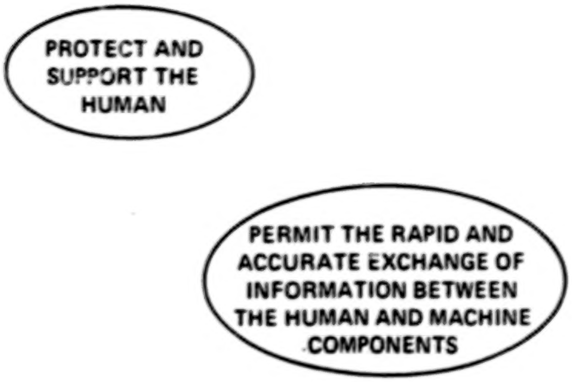
DIFFERENT COMPONENTS (HUMAN AND MACHINE) HAVE BEEN ALLOCATED DIFFERENT FUNCTIONS WITHIN THE SYSTEM

AND

THE DIFFERENT COMPONENTS CANNOT PERFORM THEIR OWN ALLOCATED FUNCTIONS IN AN OPTIMAL MANNER WITHOUT INFORMATION WHICH CAN ONLY BE SUPPLIED FROM ANOTHER COMPONENT

PURPOSE OF A CREWSTATION

Having decided to use a human as a system component, we must protect and support the human so that he or she is not damaged and will continue to function in an optimal manner. As human engineers, we need to protect and support the human component. This is no different from a hardware engineer's need to protect and support hardware components to ensure that they will continue to function optimally during a mission. This is one of the purposes of a crewstation. However, the primary reason that the human is a component of the system is to accomplish various perceptual and cognitive functions which, as noted, requires the exchange of information. This then is the primary purpose of a crewstation, to permit the rapid and accurate exchange of information between human and machine components.


PROTECT AND SUPPORT THE HUMAN
PERMIT THE RAPID AND ACCURATE EXCHANGE OF INFORMATION BETWEEN THE HUMAN AND MACHINE COMPONENTS

DEFINITION OF "TECHNOLOGY"

Having identified the major purpose of a crewstation we must now ask how future crewstation designs can be improved. Let's begin with a definition of technology which indicates that our technology is the array of methods and techniques by which crewstations are designed and validated. Secondly, its subject matter is the exchange of information between humans and machines. Such techniques must be rational, uncontaminated with subjective opinion, and organized on scientific data and principles. Many of our earlier-developed techniques do not meet these criteria but continue to be used despite the fact that superior methods are now available. Finally, the practical purpose or goal of crewstation design and validation technology is to optimize required information exchanges from both a cost and effectiveness standpoint.

"THOSE METHODS, TECHNIQUES, PROCEDURES, etc.

WHICH ARE RELATED TO A SPECIALIZED SUBJECT MATTER

AND WHICH ARE ORGANIZED ON SCIENTIFIC PRINCIPLES

FOR ACHIEVING A PRACTICAL PURPOSE."

METHODS USED IN A TECHNOLOGY AREA ARE DEPENDENT ON LEVEL OF MATURITY

All technologies, and human engineering is no exception, start with intuitive or common sense approaches to design problems. Designers rely on their own skills and intelligence and do what they think best. Human engineering arose, primarily, because equipment engineers were failing to appropriately consider the capabilities and limitations of the humans who had to use equipment designers were building. Much of human engineering is centered on what is traditionally called the man-machine interface problems which are historically identified with the crewstation design problem.

Crewstation design technology reached a second level of maturity when early experiments conducted in psychology laboratories were able to demonstrate certain univariate relationships between the speed and accuracy of information exchange and different parameters of display or control design or of device layouts. Indeed, a great deal of such univariate relationships established over the early years of human engineering became the basis for the human engineering textbooks, handbooks, guidelines, and even our engineering standards. Such data and information, because they are univariate in scope are presented in separate chapters or subsections of these publications. While univariate relationships may be important to the speed and accuracy of information exchanges, designers are not given necessary guidance on the relative importance of each of these relationships and must pick and choose which guidelines he deems most important.

The establishment of the multivariate relationships is needed so that the totality of information exchanges required between the human and the machine can be considered simultaneously. Crewstation design is analgous to statistics and physics in that we must solve simultaneous equations. The problems we face for future crewstation design are really no different from those we have always faced. While some new relationships may have to be established, our central problem in crewstation design is that we have failed to establish valid multivariate models and to require that all crewstation designers use them. Instead, our technology is still dominated by the whims of personal opinion.

- "INTUITIVE" AND "COMMON SENSE" APPROACHES
- ISOLATED UNIVARIATE RELATIONSHIPS ESTABLISHED
- COMPLEX MULTIVARIATE RELATIONSHIPS ESTABLISHED
- SPECIFICATION OF PROCESS TO USE WHICH, IF FOLLOWED, ALWAYS LEADS TO BEST ENGINEERING DESIGN POSSIBLE

"THE GOAL OF TECHNOLOGY DEVELOPMENT IS TO REQUIRE LESS AND LESS RELIANCE ON PERSONAL OPINION!"

DESIGN & VALIDATION TECHNOLOGY

With the foregoing remarks in mind, let us now examine the four phases of system development:

the development of functional requirements
the allocation of functions to components
the development of design specifications, and
the validation of the design.

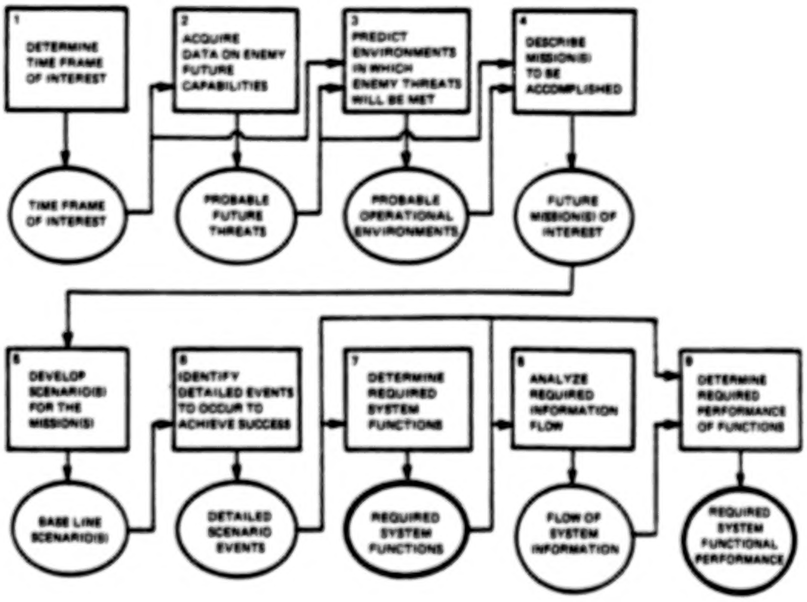
As we review the design process, you may wish to ask yourselves to what extent do we really lack adequate data, what are those missing data, and most importantly, what methods are required to make use of the relevant data so that crewstation design and validation ceases to be whimsical and instead becomes objective, standardized and disciplined.

- DEVELOP FUNCTIONAL REQUIREMENTS
- ALLOCATE FUNCTIONS
- DEVELOP DESIGN
- VALIDATE DESIGN

DEVELOP FUNCTIONAL REQUIREMENTS

Functional requirements are developed to be sure we know what it is we need to design and what capabilities it must possess. Here we indicate a sequence of activities with the ellipses representing the desired outputs or products of these activities. They are generic ones which are applicable to the design of any system. Each activity shown is logically necessary for one or more succeeding activities. For example, because equipment technology and the capability of our own and potential adversaries's systems may undergo change, it is necssary to first determine the timeframe for which a particular system is needed. Knowing this, we project the probable capabilities of adversary systems and to predict under what operational environments the adversary will be confronted. Next, we describe what our goals and objectives are for these confrontations so that we may specify more clearly what missions we need to accomplish with the system to be designed. Having estimates of enemy capability, environment, and missions to be accomplished, we then develop possible scenarios such that the system to be designed can accomplish its mission. From baseline scenarios detailed events are identified which must occur to achieve success. These provide us with indications of what functions must be accomplished by our system to achieve success. Because many different functions must be accomplished at the same time, optimal performance requires coordination of these functions which, in turn, requires the flow of information among the functional elements. Finally, we make estimates of how accurately and rapidly these various functions must be accomplished.

Functional requirements are developed to derive what functions must occur and at what level they must be performed. They don't tell us how they can be accomplished. This is the responsibility of subsequent phases of system development.


1
DETERMINE TIME FRAME OF INTEREST
2
ACQUIRE DATA ON ENEMY FUTURE CAPABILITIES
3
PREDICT ENVIRONMENTS IN WHICH ENEMY THREATS WILL BE MET
4
DESCRIBE MISSION(S) TO BE ACCOMPLISHED
TIME FRAME OF INTEREST
PROBABLE FUTURE THREATS
PROBABLE OPERATIONAL ENVIRONMENTS
FUTURE MISSION(S) OF INTEREST
5
DEVELOP SCENARIO(S) FOR THE MISSION(S)
6
IDENTIFY DETAILED EVENTS TO OCCUR TO ACHIEVE SUCCESS
7
DETERMINE REQUIRED SYSTEM FUNCTIONS
8
ANALYZE REQUIRED INFORMATION FLOW
9
DETERMINE REQUIRED PERFORMANCE OF FUNCTIONS
BASE LINE SCENARIO(S)
DETAILED SCENARIO EVENTS
REQUIRED SYSTEM FUNCTIONS
FLOW OF SYSTEM INFORMATION
REQUIRED SYSTEM FUNCTIONAL PERFORMANCE

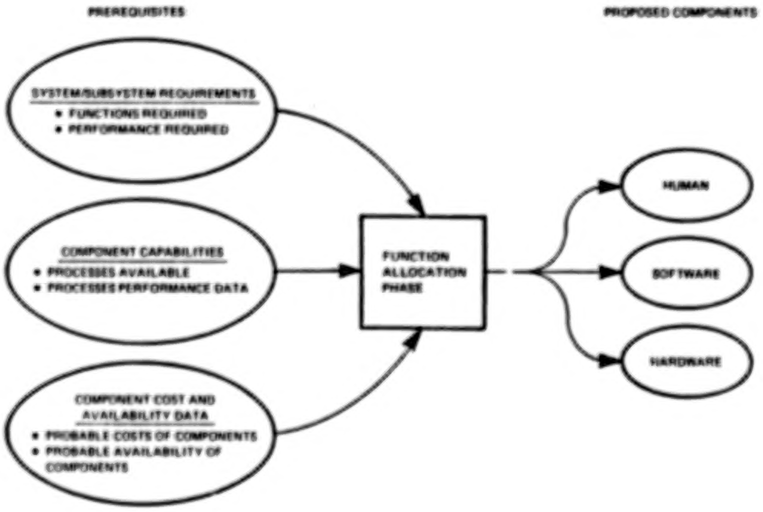
ORIGINAL PAGE IS
OF POOR QUALITY

ALLOCATE FUNCTIONS

Within any complex system, functions which are highly related (i.e., those which must exchange a great deal of information) are usually organized together into what we call subsystems. Regardless of how these functions are organized, they still must be accomplished by components or assemblies of components. We really only have a limited number of types of components to choose from: human, software, or hardware. The allocation of functions to different components is what the function allocation phase of system design is all about.

Past methods and procedures to allocate functions have not been particularly systematic or rational. Allocation methods have greatly relied on expert opinion which, unfortunately, has not been equal to the task. In most cases, the functional allocation process is dominated by strategies which, by default, leave human components with all those functions which cannot or will not be done by hardware or software components. Little regard is paid to the problem of whether the human components will be able to perform these residual functions or to the level of performance expected of the human component. Not surprisingly, the human components of a system are often overloaded.

At least three different types of information are required to make rational decisions during the function allocation phase. First, valid functional and performance specs which should have been developed in the previous phase are needed. Secondly, valid data about the capabilities and limitations of the potential components to which various functions could be allocated must be known. Finally, valid data is required on whether sufficient numbers of such components will be available during the timeframe of interest and what the cost of these components will be.


PREREQUISITES
PROPOSED COMPONENTS
SYSTEM/SUBSYSTEM REQUIREMENTS
• FUNCTIONS REQUIRED
• PERFORMANCE REQUIRED
COMPONENT CAPABILITIES
• PROCESSES AVAILABLE
• PROCESSES PERFORMANCE DATA
COMPONENT COST AND AVAILABILITY DATA
• PROBABLE COSTS OF COMPONENTS
• PROBABLE AVAILABILITY OF COMPONENTS
FUNCTION ALLOCATION PHASE
HUMAN
SOFTWARE
HARDWARE

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COMPONENT CAPABILITIES

As mentioned earlier, most functions allocated, either by design or default, to humans deal with information processing and decision making. Particular capabilities of interest about the human, then, must be those processes which permit the human to store and retrieve information, to perform complex information manipulations, and to exchange information with other types of components. Our lack of understanding of human capabilities and limitations in these realms does not permit us to make sufficiently good predictions of the levels of performance obtainable from humans to ensure that all functions allocated to them can be performed as required.

A major problem facing system designers in the future is whether various cognitive functions should be allocated to humans or intelligent machines. Presently, we can't specify the capabilities or limitations of either of these types of components.

As crewstation designers we are also interested in what information will have to be exchanged between humans and intelligent machines and how those exchanges can be optimally accomplished.

PROCESSES COMPONENT CAN PERFORM:

- INFORMATION STORAGE AND RETRIEVAL
- INFORMATION MANIPULATION (COGNITIVE)
- INFORMATION EXCHANGE
  - MODES OF RECEIVING INFO
  - MODES OF OUTPUTTING INFO

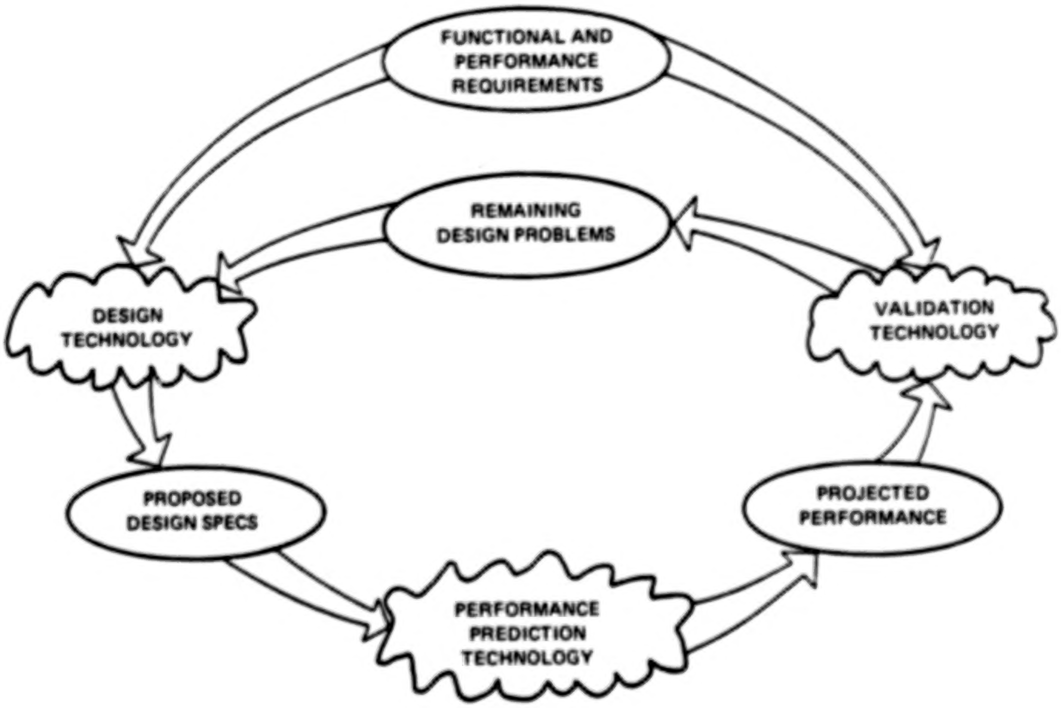
LEVELS OF PERFORMANCE OBTAINABLE:

- ACCURACY
- TIME REQUIRED
- COMPLEXITY OF PROCESSING ACHIEVABLE
- ACCURACY/TIME/COMPLEXITY TRADE-OFFS

DESIGN, PREDICTION, & VALIDATION

Earlier it was stated that, traditionally, the final two stages of system design were design specification and design validation. This diagram gives a more truthful representation of what occurs after the function allocation phase. It also points out that there are actually three kinds of technology required: design, performance prediction, and validation.

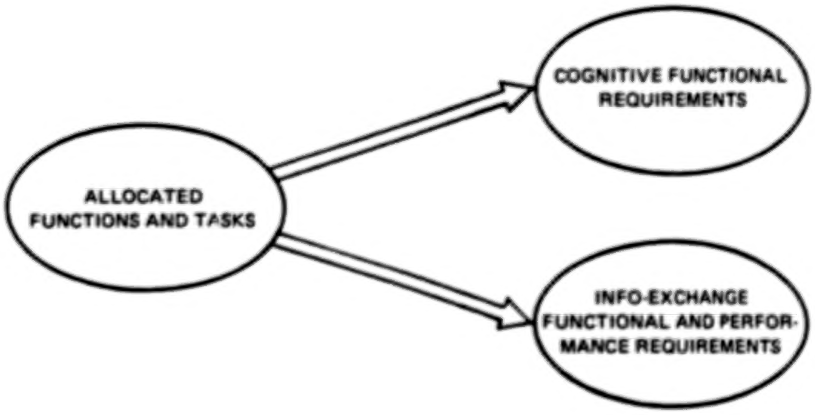
Design technology is concerned with how one translates functional and performance requirements into design specifications. Performance prediction technology is concerned with how one translates proposed design specs into statements of projected performance of the human component and/or the system as a whole. Validation technology is concerned with how one compares projected performance with required performance to discover any remaining design problems which require correction or redesign. Thus, design, prediction, and validation is an iterative process which, hopefully, gets the design team ever closer to an optimal and cost effective design. Each of these technology areas requires different methods and tools, and no single technique should be expected to accomplish all three purposes. If, of course, we had the perfect design tool or process we would not have to be concerned with performance prediction or validation since, by being perfect, it would arrive at an optimal design which would meet all the functional and performance requirements.


FUNCTIONAL AND PERFORMANCE REQUIREMENTS
REMAINING DESIGN PROBLEMS
DESIGN TECHNOLOGY
VALIDATION TECHNOLOGY
PROPOSED DESIGN SPECS
PROJECTED PERFORMANCE
PERFORMANCE PREDICTION TECHNOLOGY

DESIGN OF A CREWSTATION

Crewstation design is no exception to the rule that we must start by knowing the functional and performance requirements. Various allocated functions and tasks for the human component must be examined to determine both their cognitive and information exchange functional and performance requirements. This might be a relatively simpler task if earlier phases of system design paid adequate attention to these concerns for all required system functions. Unfortunately, this is not the usual case for many tasks involving information management and flow.

One of the problems confronting the human factors engineers is that even if required task times and accuracies have been specified, we usually don't know how much of that time or accuracy should be allocated for the cognitive functions and how much for the information exchange ones. Cognitive funtional and performance requirements should, of course, be identified since they are the basis for many of the selection and training decisions. But information exchange functional and performance requirements are the ones of particular interest to the crewstation design team since the exchange of information between the human and machine components is the primary purpose of the crewstation. How, then can we specify these requirements?


COGNITIVE FUNCTIONAL REQUIREMENTS
ALLOCATED FUNCTIONS AND TASKS
INFO-EXCHANGE FUNCTIONAL AND PERFORMANCE REQUIREMENTS

INFORMATION-EXCHANGE FUNCTIONAL & PERFORMANCE REQUIREMENTS SPECIFICATIONS

After many years of considering crewstation design problems it appears such requirements can be adequately specified with five pieces of data for each proposed operator task. First, what information must be exchanged? Secondly, will the required exchange be to or from the operator? Said another way, which of the required information exchanges are inputs to the operator and which are outputs from the operator. The third specification concerns when these exchanges must take place and includes how often they would occur as well. The fourth specification deals with the required accuracy of each exchange and the last with how rapidly each must be accomplished.

These requirements don't tell us how to design the crewstation but they supposedly would tell us what the crewstation is supposed to be able to accomplish. Before one makes decisions on such things as which exchanges should be accomplished by voice and which by manual controls and visual displays, it seems most reasonable to know the totality of requirements for information exchanges to and from the human. Before one decides how some multipurpose two-dimension advanced visual display could be used it seems worthwhile to have an appreciation for all the information which might be exchanged through it. Before one goes off to design some artificial intelligence system it seems reasonable to understand fully what information will have to be exchanged between it and the human elements in the system.

Any crewstation design team needs to fully understand all the design requirements before it can hope to achieve an optimal simultaneous solution to the problem.

- WHAT INFORMATION MUST BE EXCHANGED
- DIRECTION OF THE EXCHANGE (TO OR FROM HUMAN)
- WHEN THE INFORMATION MUST BE EXCHANGED
- ACCURACY REQUIREMENTS FOR THE INFO EXCHANGED
- SPEED REQUIREMENTS FOR THE INFO EXCHANGED

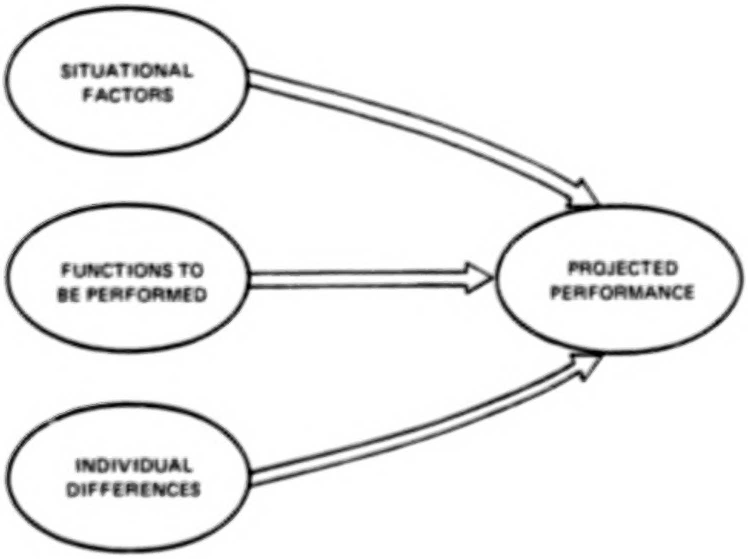
PREDICTING PERFORMANCE

Before discussing some of the design technology programs which help translate information exchange requirements into crewstation design specs it is useful to discuss the problem of predicting human and system performance. In this diagram I have indicated that the level of performance attainable by a human is a function of many factors which can be subsumed under three categories:

the situational factors in which the human's task is embedded,

The particular functions which are expected of the human, and

the individual differences among humans.


SITUATIONAL FACTORS
FUNCTIONS TO BE PERFORMED
INDIVIDUAL DIFFERENCES
PROJECTED PERFORMANCE

SITUATIONAL FACTORS

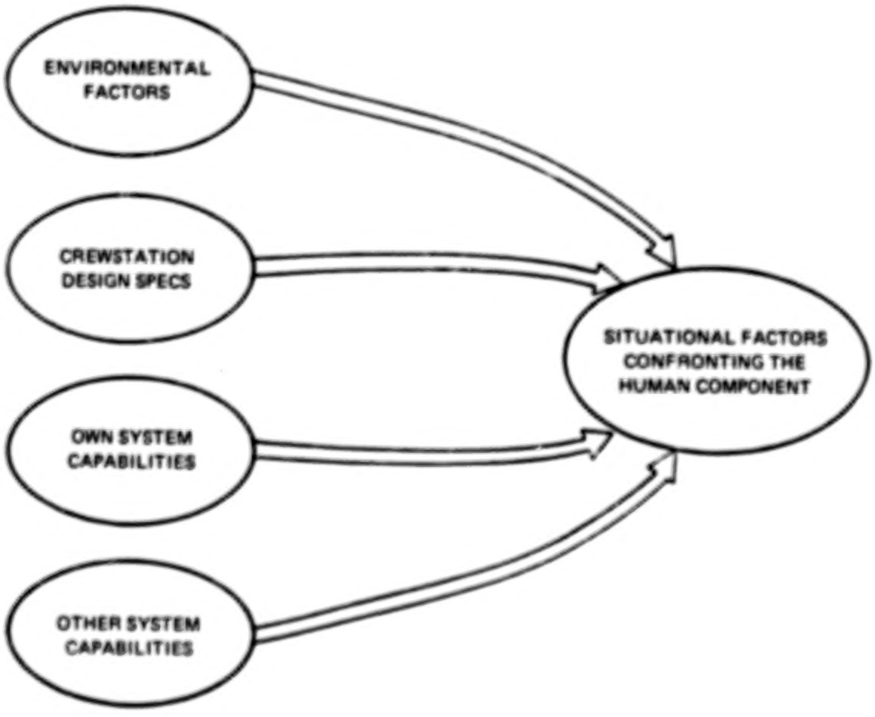
Situational factors includes all those outside the human component which can make a required human task easier or more difficult, complex or simple, a piece of cake or a nightmare. These include:

Environmental Factors (vibration, G-forces, temperature extremes, noise and so forth as well as all the protection and support equipment with which the human is encumbered.)

Crewstation Design Specs (all the devices through which the information exchanges must be carried out, including type of device selected, how labeled, where located, what format the information is in or must be put in by the human, and so forth.)

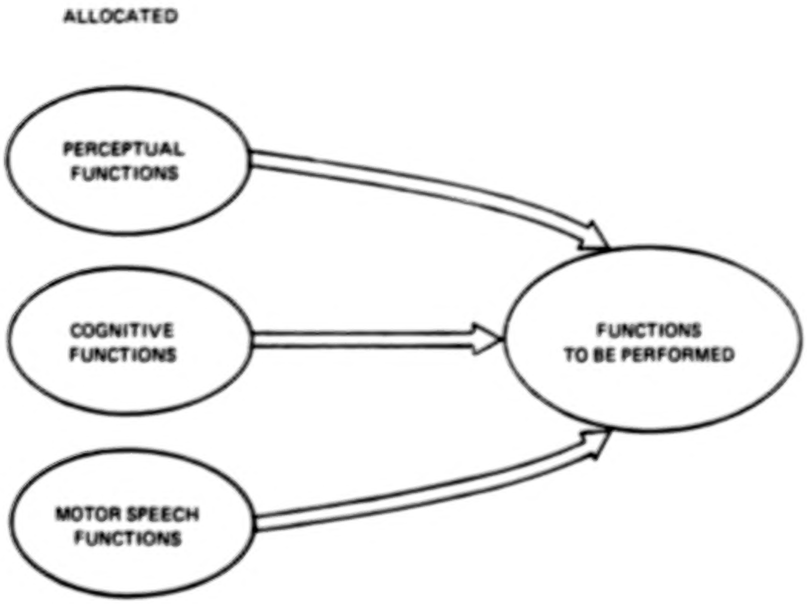
Other Capabilities of Our Own System (includes the capabilities and limitations of all the remaining hardware or software in our system, which can effect the information with which the human must work, and the options available to the human.)

Capabilities of Other Systems (the fact that an adversary may possess more capability can obviously effect the speed and accuracy for certain of the human functions within our own system.)


ENVIRONMENTAL FACTORS
CREWSTATION DESIGN SPECS
OWN SYSTEM CAPABILITIES
OTHER SYSTEM CAPABILITIES
SITUATIONAL FACTORS CONFRONTING THE HUMAN COMPONENT

FUNCTIONS TO BE PERFORMED

The particular tasks and functions allocated to the human is the second category of factors which influence the performance attainable by the human and, consequently, by the system as well. We must determine to what extent each allocated task requires various types of perceptual, cognitive, and motor and speech functions. Different combinations of these functions will effect how well humans can perform that given task not only when it is the only task the human has, but when it is but one of many responsibilities the human component has at any point in the mission.

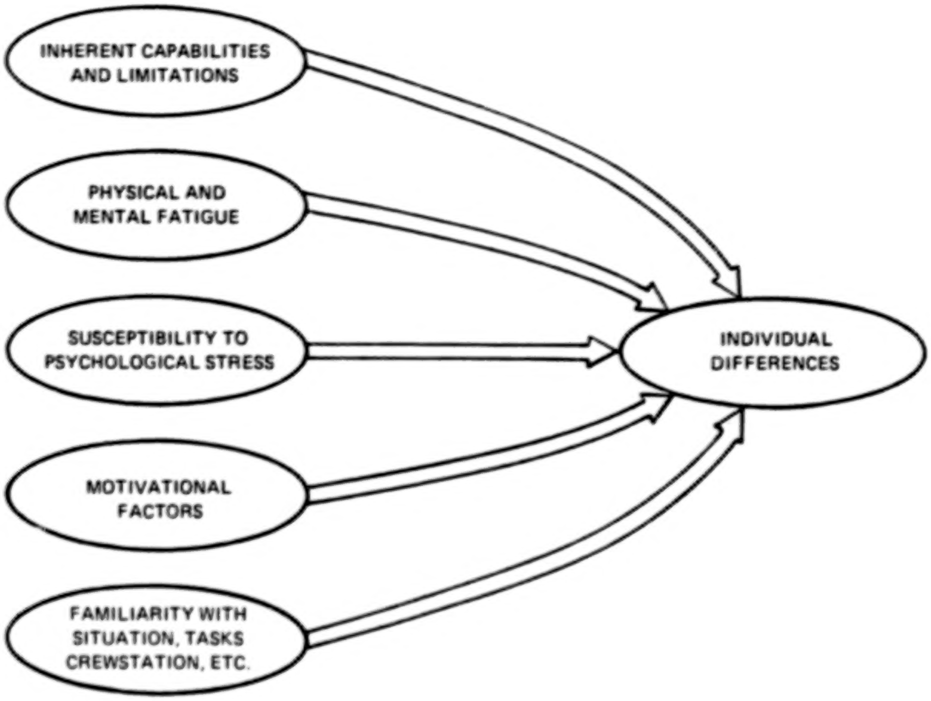

ALLOCATED
PERCEPTUAL FUNCTIONS
COGNITIVE FUNCTIONS
MOTOR SPEECH FUNCTIONS
FUNCTIONS TO BE PERFORMED

INDIVIDUAL DIFFERENCES

If the preceding categories were not sufficient to make it obvious that prediction of human and system performance is difficult, we must also consider that human components, unlike hardware and software components, have great individual differences. Of all data established by psychologists over the years, that of the reality of individual differences is best grounded experimentally. Individual differences are not merely limited to inherent skills and abilities, but are also found in areas such as physical and mental fatigue, he susceptibility to psychological stressors, a variety of motivational factors, and those differences attributable to amount and quality of training and experience.

Without a valid performance prediction technology asa part of the iterative design and validation process we have little hope of being able to discover remaining design problems until it is too late to do anything about them.

Discussion of the complexity of performance prediction underscores the earlier comments about the multivariate nature of the crewstation design and validation problem.

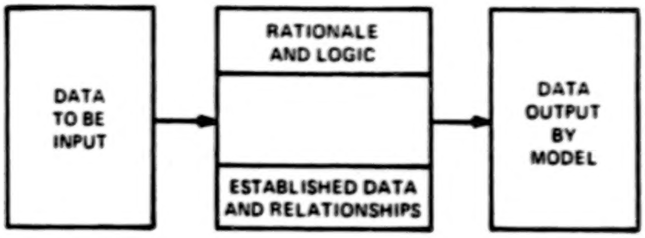

INHERENT CAPABILITIES AND LIMITATIONS
PHYSICAL AND MENTAL FATIGUE
SUSCEPTIBILITY TO PSYCHOLOGICAL STRESS
MOTIVATIONAL FACTORS
FAMILIARITY WITH SITUATION, TASKS CREWSTATION, ETC.
INDIVIDUAL DIFFERENCES

DESIGN AID MODELS

The methods (intuitive or otherwise) by which designers translate functional and performance requirements into crewstation design specs can be represented by the diagram shown. For design, the inputs are the functional requirements, component capabilities, and component costs and availability. The outputs from this process are the design specs.

In similar fashion, the methods by which design specs are translated into performance projections can also be represented by the same diagram, but the inputs are now data about the situational factors, the allocated human tasks and functions, and individual differences. The outputs here are the performance projections.

The diagram shown thus represents a general model for both design and prediction processes which must occur during crewstation design. The goal of technology development is to replace essentially intuitive processes which are found in the different blocks with objective, standardized, and scientifically-based methods.

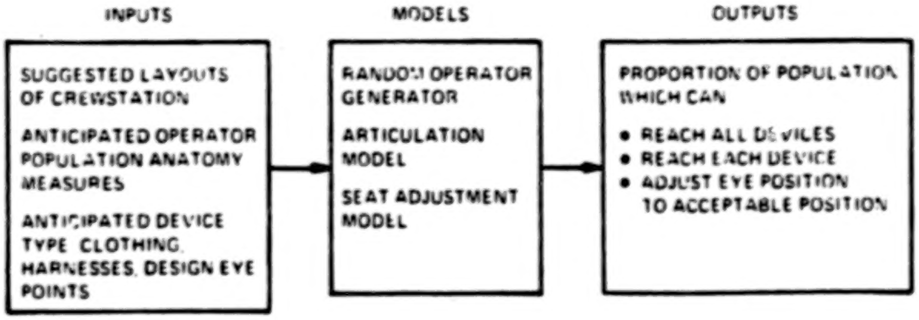


ENDURING CREWSTATION DESIGN PROBLEMS:

LOCATING PANELS & CONSOLES

An enduring crewstation design problem has been deciding where to place panels and consoles so that humans operating within that crewstation can see all the displays and reach all the controls mounted on those panels and consoles. Until recently, crewstations were designed according to guidelines based on general population anthropometry. Mockups of the crewstation were then constructed and, typically, manikins representing the fifth and ninety-fifth percentile humans were used to determine display and control accessibility. Such an approach would be entirely satisfactory if skeletal size and limb length were controlled by a single factor.

Factor analysis of the intercorrelation matrix of hundreds of different anthropometric measures shows that this is not the case. Therefore, the approach to panel and console placement just discussed is not scientifically based. The CAR (Crewstation Assessment of Reach) computer program, however, takes into account the multivariate nature of anthropometry and can more accurately predict what proportions of a given population can be accomodated by a proposed crewstation layout. Not only can it provide such answers, it can do it without having to construct a physical mockup, and it can indicate which panels are most responsible for any remaining accomodation problems.


INPUTS
MODELS
OUTPUTS
SUGGESTED LAYOUTS OF CREWSTATION
ANTICIPATED OPERATOR POPULATION ANATOMY MEASURES
ANTICIPATED DEVICE TYPE CLOTHING, HARNESSES, DESIGN EYE POINTS
RANDOM OPERATOR GENERATOR
ARTICULATION MODEL
SEAT ADJUSTMENT MODEL
PROPORTION OF POPULATION WHICH CAN
• REACH ALL DEVICES
• REACH EACH DEVICE
• ADJUST EYE POSITION TO ACCEPTABLE POSITION

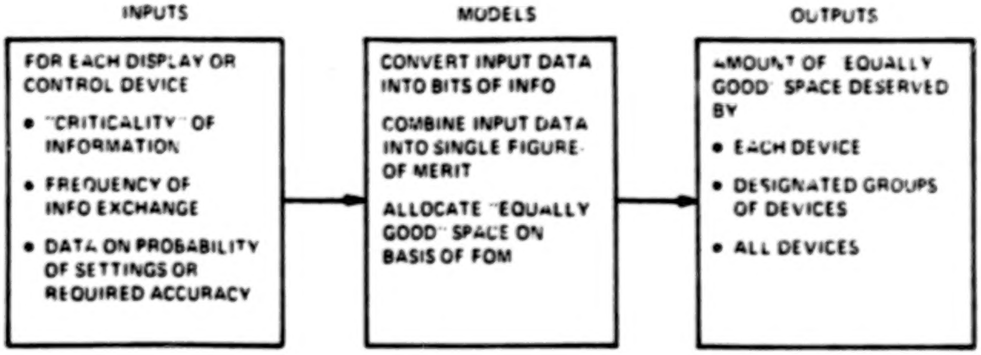
CREWSTATION ASSESSMENT OF REACH (CAR) PROGRAM

ENDURING CREWSTATION DESIGN PROBLEMS:

ALLOCATING SPACE FOR DISPLAYS & CONTROLS

A related problem in crewstation design is deciding how large various displays and controls should be, and how much panel space is deserved by a particular group of display and controls. In the past, subsystem engineers were allocated space on the basis of how large the black boxes were which connected to its displays and controls. Too often, the subsystem engineer with the most difficult black box design problem would be the last to know how much space he actually needed and would have to settle for the remaining, unallocated panel space.

The CUBITS computer program assumes that panel space is provided in a crewstation to house information exchange devices and should be allocated strictly on the basis of how much information will be exchanged, and how critical the exchange of information will be to mission success. The CUBITS program, therefore, attempts to allocate panel space so as to optimally meet information exchange requirements. It accomplishes this by computing, for each device, a single figure of merit based on information theory. It thus takes into account the multivariate nature of information exchange requirements.


INPUTS
MODELS
OUTPUTS
FOR EACH DISPLAY OR CONTROL DEVICE
• "CRITICALITY" OF INFORMATION
• FREQUENCY OF INFO EXCHANGE
• DATA ON PROBABILITY OF SETTINGS OR REQUIRED ACCURACY
CONVERT INPUT DATA INTO BITS OF INFO
COMBINE INPUT DATA INTO SINGLE FIGURE-OF MERIT
ALLOCATE "EQUALLY GOOD" SPACE ON BASIS OF FOM
AMOUNT OF "EQUALLY GOOD" SPACE DESERVED BY
• EACH DEVICE
• DESIGNATED GROUPS OF DEVICES
• ALL DEVICES

CRITICALITY, UTILIZATION, AND BITS (CUBITS) PROGRAM

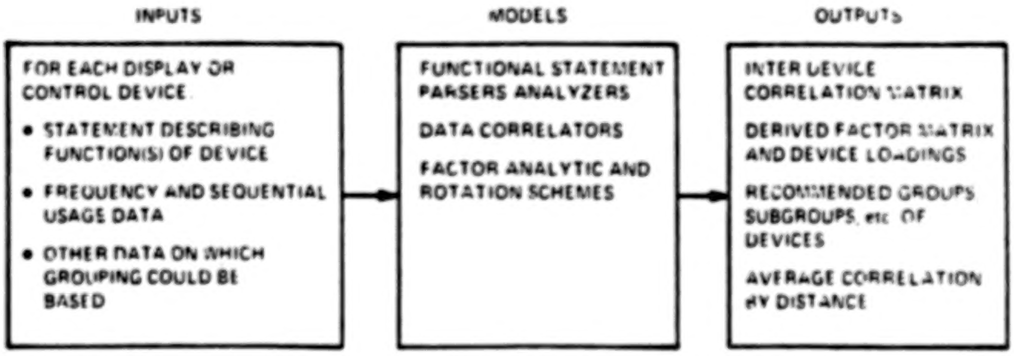
ENDURING CREWSTATION DESIGN PROBLEMS:

GROUPING VISUAL DISPLAYS & MANUAL CONTROLS

Yet another enduring crewstation design problem is deciding which displays and controls should be grouped together and how they should be arranged. Various human engineering handbooks and standards list at least fourteen different, and often overlapping and/or conflicting, principles by which information exchange devices are to be grouped together with little or no guidance on the relative importance of these different principles. It is no small wonder, then, that panels from different equipment manufacturers are difficult, if not impossible, to use in what one might call a well integrated crewstation.

GROUP is an extremely sophisticated computer program capable of determining statistical relationships among devices based on their functions, sequences in which they are used, and other parameters by which information exchange devices might be grouped and arranged. This program utilizes factor analysis to determine the number of dimensions required to account for these interrelationships. It can perform sensitivity analyses to determine, for example, the impact of giving more weight to grouping by sequence than, say, grouping by function. Such a decision may increase information exchange rates during operational missions, but may require additional training time for operators to learn where the displays and controls are located.

While no two-dimensional surface, which is basically what the console and panel surface of a crewstation is, can account for all the dimensions required to account for the device correlations, the GROUP program can rapidly obtain the two dimensions which will account for the most correlated variance. Within the constraint of two dimensional surfaces, then, it can lead to an optimum strategy for grouping information exchange devices.


INPUTS
MODELS
OUTPUTS
FOR EACH DISPLAY OR CONTROL DEVICE
• STATEMENT DESCRIBING FUNCTION(S) OF DEVICE
• FREQUENCY AND SEQUENTIAL USAGE DATA
• OTHER DATA ON WHICH GROUPING COULD BE BASED
FUNCTIONAL STATEMENT PARSERS ANALYZERS
DATA CORRELATORS
FACTOR ANALYTIC AND ROTATION SCHEMES
INTER DEVICE CORRELATION MATRIX
DERIVED FACTOR MATRIX AND DEVICE LOADINGS
RECOMMENDED GROUPS SUBGROUPS, etc. OF DEVICES
AVERAGE CORRELATION BY DISTANCE

GROUPING BY FUNCTION, SEQUENCE, AND OTHER PARAMETERS PROGRAM

ENDURING CREWSTATION DESIGN PROBLEMS:

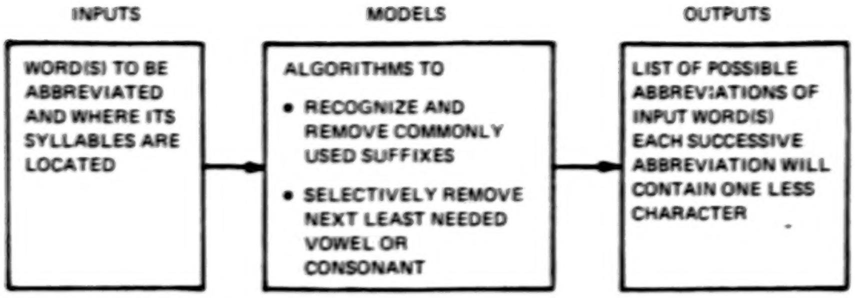
ABBREVIATING WORDS IN LABELS & LEGENDS

Because it may be impossible for operators to learn and rapidly recall where the hundreds of displays and controls are located in a crewstation, and because different information is often exchanged on display and control devices which have highly similar appearances, it is usually desirable, if not absolutely necessary, to provide labels and legends describing what information is being exchanged on each device. Because of both limited panel space as well as the complexity of the descriptor titles, many labels may be too lengthy to be placed on the panel without shortening the descriptors in some fashion. A favorite recourse of crewstation designers has been to utilize abbreviations of one or more of the words in the descriptor.

Originally, this led to each equipment manufacturer choosing whatever abbreviation he deemed appropriate which resulted in the same word being abbreviated in different ways in the same aircraft. To combat this chaotic and confusing situation the military ultimately developed a single, standard abbreviation for each of a rather large number of words commonly used in aircraft. Unfortunately, the standard abbreviation chosen was decided upon by a relatively small panel of individuals who based their choices on criteria such as what, subjectively, seemed acceptable to them or what they believed was the abbreviation most frequently used by industry at that time rather than on experimental data on the speed and accuracy of interpreting alternative abbreviations for the same word.

The ABBREV computer program incorporates a variety of algorithms for how abbreviations should be formed so that speed and accuracy of interpretation will be optimized for the number of letters remaining in the abbreviation. The ABBREV program will usually derive an abbreviation of a given length which is identical to the standard abbreviation. This suggests that the standardization panel and/or industry was intuitively using similar algorithms. However, there are also many instances in which ABBREV derived a different solution for the same number of letters. This raises the issue of whether those standard abbreviations which depart from the algorithm are inferior or superior. A review of abbreviations in existing aircraft revealed that many instances of non-standardized abbreviations were still being used despite the published standard abbreviations. Some of these were in agreement with the algorithms but many were not. This raised a second question about the possible superiority of non-standard abbreviations over either the standardized or the ABBREV-derived ones.

In an experimental study conducted at NADC, the ABBREV-derived abbreviations were comprehended more rapidly, on the average, than either the published standardized abbreviations or equal-lengthed, non-standardized abbreviations. ABBREV appears, then, to not only produce superior abbreviations for the same number of characters, but also provides even more rapidly comprehended abbreviations if sufficient space exists to permit more characters than were in the original standardized abbreviation.


INPUTS
MODELS
OUTPUTS
WORD(S) TO BE ABBREVIATED AND WHERE ITS SYLLABLES ARE LOCATED
ALGORITHMS TO
• RECOGNIZE AND REMOVE COMMONLY USED SUFFIXES
• SELECTIVELY REMOVE NEXT LEAST NEEDED VOWEL OR CONSONANT
LIST OF POSSIBLE ABBREVIATIONS OF INPUT WORD(S) EACH SUCCESSIVE ABBREVIATION WILL CONTAIN ONE LESS CHARACTER

ABBREVIATION ALGORITHMS (ABBREV) PROGRAM

ENDURING CREWSTATION DESIGN PROBLEMS:

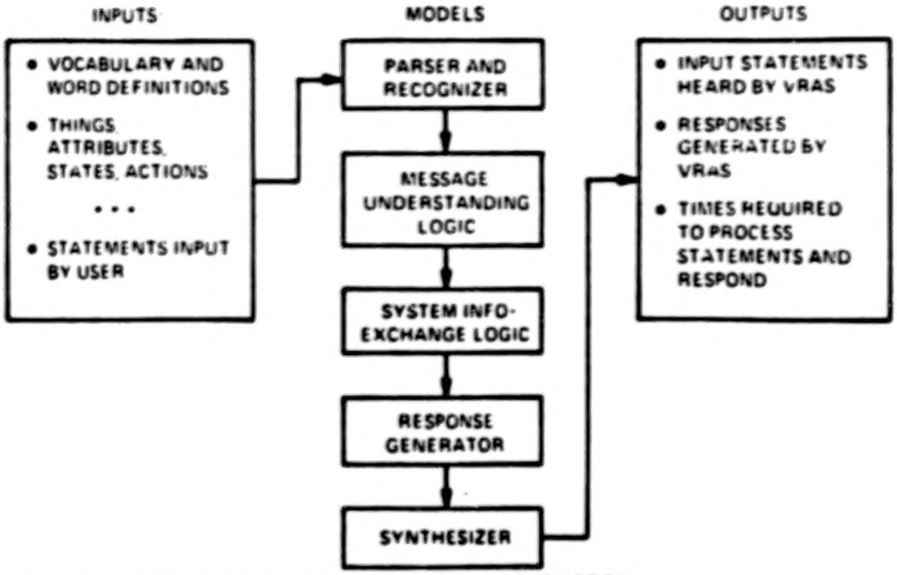
DESIGN OF VOICE-INTERACTIVE SYSTEMS

Voice-interactive systems represent a potentially attractive alternative to manual controls and visual displays for the exchange of some types of information. If the use of voice is constrained to only a relatively few applications in an aircraft, then only a few words are required in an information exchange utterance. If voice is used for a wide variety of applications, then more words, on the average, are required in each utterance to identify the states, the attributes, and the things on which information is being exchanged. For example, if voice is used only to turn one piece of equipment on or off then one does not have to identify the equipment but can merely voice the desired state.

While it is true that multiple-word utterances take longer to say, and thus slow down the information exchange rate, even a five- or six-word utterance permits hundreds of different applications for an interactive voice system. The net result sacrifices extremely fast information exchanges for a few applications in favor of moderately fast information exchanges for many applications.

The VRAS (Voice Recognition And Synthesis) system was designed to handle the processing of multiple-word utterances requiring syntactic and semantic considerations. The VRAS system contains many different knowledge bases such as permitted grammars; words in its vocabulary and their meanings; permitted synonyms; information about the names of systems, subsystems, and components of those subsystems; names of attributes which can be discussed; states those attributes can assume; which of those attributes can be changed by voice commands; how to form responses; and so forth. As such, VRAS can be appropriately described as an application of artificial intelligence for the handling of voiced information exchanges.

VRAS can be used to help resolve a wide variety of issues connected with the potential use of interactive voice systems including probable times for various types of information exchanges, potential advantages and disadvantages of permitting synonyms, probable vocabulary size for desired applications, and so forth. While it does not attempt to suggest which information exchanges should be accomplished by voice, it does aid the crewstation designer in determining some of the important implications of using voice for various purposes.


INPUTS
MODELS
OUTPUTS
• VOCABULARY AND WORD DEFINITIONS
• THINGS, ATTRIBUTES, STATES, ACTIONS
• • •
• STATEMENTS INPUT BY USER
PARSER AND RECOGNIZER
MESSAGE UNDERSTANDING LOGIC
SYSTEM INFO-EXCHANGE LOGIC
RESPONSE GENERATOR
SYNTHESIZER
• INPUT STATEMENTS HEARD BY VRAS
• RESPONSES GENERATED BY VRAS
• TIMES REQUIRED TO PROCESS STATEMENTS AND RESPOND

VOICE RECOGNITION AND SYNTHESIS (VRAS) SYSTEM

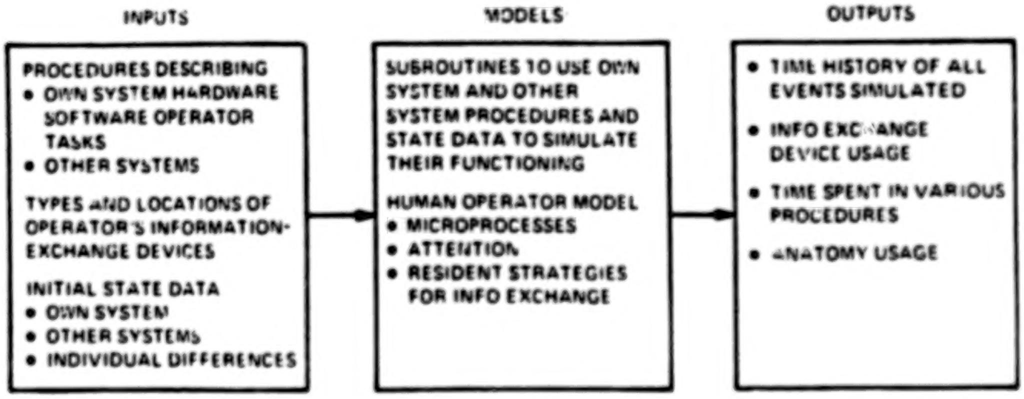
ENDURING CREWSTATION DESIGN PROBLEMS:

PREDICTING HUMAN & SYSTEM PERFORMANCE

Perhaps the most sophisticated crewstation design and validation aid available is the HOS (Human Operator Simulator) program. HOS is useful for predicting both human and overall system performance for a specified proposed system. In many ways it is similar to the software program used to drive a training simulator in that the hardware and software of one's own system as well as adversary systems are simulated by digital computer subroutines. What makes HOS unique is that it also contains a resident model of a general purpose, goal-oriented, adaptive human operator that can be modified to become any type of desired operator. This modification is accomplished through the use of the special-purpose, English-like HOPROC (Human Operator Procedure) language to describe the various tasks which have been allocated to that operator.

The HOS program permits the investigation of the impact of such design decisions as the reallocation of various tasks from human to machine or vice versa, changes in operator procedures to accomplish various assigned tasks, relocation of displays and controls within the crewstation, and so forth. Special analysis programs are available for colating and analyzing HOS output data of particular interest to crewstation designers.

While HOS, because it simulates the entire system, is expensive the use, it is very likely that it may be far more expensive to not utilize it since it offers what is undoubtedly a vastly superior technology for more validly predicting both human and system performance as early as possible so that potential design problems can be recognized sufficiently early to correct them.


INPUTS
MODELS
OUTPUTS
PROCEDURES DESCRIBING
• OWN SYSTEM HARDWARE SOFTWARE OPERATOR TASKS
• OTHER SYSTEMS
TYPES AND LOCATIONS OF OPERATOR'S INFORMATION-EXCHANGE DEVICES
INITIAL STATE DATA
• OWN SYSTEM
• OTHER SYSTEMS
• INDIVIDUAL DIFFERENCES
SUBROUTINES TO USE OWN SYSTEM AND OTHER SYSTEM PROCEDURES AND STATE DATA TO SIMULATE THEIR FUNCTIONING
HUMAN OPERATOR MODEL
• MICROPROCESSES
• ATTENTION
• RESIDENT STRATEGIES FOR INFO EXCHANGE
• TIME HISTORY OF ALL EVENTS SIMULATED
• INFO EXCHANGE DEVICE USAGE
• TIME SPENT IN VARIOUS PROCEDURES
• ANATOMY USAGE

HUMAN OPERATOR SIMULATOR (HOS) PROGRAM

COMMITTEE REPORTS

N85 14823 D17

OPERATIONAL REQUIREMENTS – SYSTEM CONCEPTS

By

Dr. J. W. Voorhees and Dr. H. L. Snyder

REPORT OF

THE OPERATIONAL REQUIREMENTS SYSTEM CONCEPTS COMMITTEE

What we want to discuss first this morning are those problems that the operational community felt were most critical to the issue of a single pilot helicopter. We began our meeting yesterday with a presentation by Virgil Graf of Bell Helicopter. Dr. Graf reviewed some advanced cockpit concepts with us; specifically, those proposed for the improved AH-1G Cobra. This review helped us to focus on many of the issues confronting us with our attempts to develop a single pilot helicopter.

What I would like to do now is to show you the Committee's recommendation for nine areas that require further research before the concept of single pilot can become feasible (see following pages). Let me qualify my remarks about these areas at the outset. Not all of the reasoning represents a consensus vote of the committee; some of the areas were of concern to only some of the committee. Also I will not be able to comment in detail on all of these areas, in some cases I will direct your questions to the appropriate member of the committee for their answers.

1. AUTOMATION

We discussed automation issues for some time, and developed a set of research issues that will have to be addressed if automation is to become a useful tool in the single pilot cockpit.

a. The first area was that of rules of priority. If several tasks are left to a pilot to do, he will set the priority for which task should be done in what order. If you automate a system, these tasks must now be prioritized by the machine. The problem is that the pilot is quite often facing different situtations when these task need to be accomplished. How do we build a machine smart enough to know how to change the rules of prioritization with the situtation?

b. The second area that was explored in the area of automation was that of personality type of the pilot. It occurred to some of the members of the committee that the pilot of our modern complex aircraft was becoming more of a system manager rather than a technician. The new pilot is not a "stick and rudder" man, rather a manager of complex electronic systems. Do we need a 45 year old man who has a Ph.D. in computer electronics as our new generation pilot, or do we need to just automate the whole thing and go back to the pilot with the leather helmet and white scarf? This question has a potentially large effect on pilot selection and training techniques, some research should be done to determine who this optimal pilot is to be.

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c. The next question that came up concerning automation was, what do you lose when you automate a system or procedure? An automated system is fine as long as it works every time, and you never ask the pilot to go back and perform the tasks manually. If the pilot does have to go back and do the job manually, is he going to have the skills to do it? If you automate the throttle on the aircraft with the addition of a fuel control unit, do not ask the pilot to use a manual throttle and a start trigger, he will not be trained to use these techniques anymore.

2. INCREASED COMPLEXITY

We discussed the area of increased complexity for some time. There were several issues that we discussed that we felt were outcomes of this increased complexity.

a. One of the major areas of concern with this increased complexity was the increased cost of training. Some of the things that you see with the Advanced Attack Helicopter, AH-64 Apache, is that the simulator being designed to support the training on the aircraft will cost almost three times what the actual helicopter costs. We noted that the cost of the new AH-64 simulator is a great deal larger than the old Link "Blue Canoe" with which we conducted our original simulator instrument training.

b. The point was also made that as complexity of our aircraft increases, we need to be able to have a better way of selecting pilots. We may not be able to take in a group of people off of the street, give them six months of training, and put them in the helicopter. We may not be able to put any pilot through a transition course for an LHX type of aircraft--we may need to start a pilot in this type of aircraft, and keep him there for his entire career.

c. The transparency of the system was also an issue. How transparent to the pilot should we make a complex system? You can have a very complex system behind the panel, but make it very simple on the outside. But when you do that, you lose some of the pilot's ability to interact with the system and understand how it works. We were not able to determine where the trade-off might lie, but there is some point where you tell him just enough about the system so he can operate it effectively.

QUESTION: What do you mean by simplicity? Do you mean a simple system, of just one that looks simple to the operator?

There is a difference in simplicity to the pilot and simplicity to the system itself. The system is going to be complex, there is little doubt about that, given what we want to do; but how much of that complexity you want to give to the pilot is a different matter. To me the head-up displays that are used now are extremely complex, and I would not work well with the moving velocity vectors, moving diamonds, attitude ladders, digital displays and other things moving around the HUD. To me that is an extremely complex way of displaying information.

3. COCKPIT WORKLOAD HIGHEST IN NAVIGATION

When we began our discussion about workload, the area that kept coming up from operational people on our committee was the issue of navigation. The feeling was that if the system can tell the pilot where he is and where he wants to go at any time, then much of the workload associated with NOE flight could be eliminated. It was also mentioned that if we go to a single crewmember helicopter, some sort of advanced navigation system is essential. It was also mentioned by the pilots that any navigation system must use passive sensors, and not put out a detectable signal. It was strongly felt that we cannot afford to go into combat in the Air-Land Battle 2000 scenario with navigation systems that put out detectable radar emissions.

QUESTION: How did the operational people feel about a GPS type of navigation system?

GPS was discussed. There are some problems with a GPS system, because you can lose it. It can be jammed or someone can take out your satellite. You are always vunerable if you are depending on an external source for your navigation information; the enemy can take out your source, and you lose your ability to navigate.

QUESTION: With those restrictions, does that leave you with only some sort of inertial navigation system?

You would need an inertial system that updates well enough so that you can figure out where you are at all times, maybe that is the direction in which we must proceed.

QUESTION: Are all of the systems that put out a signal of some sort undesirable?

I assume that everything that puts out an impulse outside of the aircraft, such as a radar altimeter, could have adverse effects as far as enemy detectability is concerned.

QUESTION: How real is the threat of detection of things like a radar altimeter by enemy radar systems? Is this just a psychological issue on the part of the pilot?

I think that a lot of this is a psychological feeling on the part of the pilot, but if the feeling exists, and the pilots can see their radar altimeters being displayed on their APR-39, then they tend to pull the circuit breaker on the emitter when encountering a combat condition. When you are sneaking around in the rain, you are trying real hard not to tell anybody where you are, if the pilot believes that some system is telling everyone where he is, he will pull the circuit breaker, so we might as well save system cost and weight.

We also felt that within the navigation framework, we wanted some way of updating or inputting navigation and mission planning data into the aircraft, using some kind of electronic media. For instance, a log-in bubble cassette or something that could be set up in flight operations prior to the pilot going to his aircraft. This capability would contain all of the mission, navigation, threat, and communication information needed for his flight.

QUESTION: Are you envisioning this type of system as being able to be updated in flight via some sort of data link?

I think that the idea of a data link was mentioned. It should be some sort of connection back to a ground unit that could communicate back and forth with short burst transmissions to re-load a mission module.

4. CREW STATION LIFE SUPPORT DESIGN

In our discussions concerning life support for crew station design, we talked about problems associated with long missions and single pilots, and current seat and control designs. The current seats, restraint devices, and control configurations impose a great deal of physiological stress on the pilot. If the pilot will not be able to let go of the controls and move around while someone else flies the helicopter, or undo his seatbelt and move around in the seat, then we had better design the cockpit system correctly in the first place. We see a lot of advantage in side-arm controllers for this type of problem, because now we can properly adjust the pilot's posture through better seat design, and take away the need for having to place his feet on pedals. The crashworthiness problem was also discussed by the committee. There was some discussion concerning the possibilities of ejection; the idea seems to be more acceptable if the aircraft has only one crewmember. It seemed to be the general consensus that looking at some sort of system with blade separation and extracting the pilot out of the top of the aircraft with some sort of rocket and pyrotechnics device could be valuable for an LHX type of aircraft.

5. AUTO HOVER AND FLIGHT TRIM CONTROLS

We discussed the need for some kind of automation for the flight controls--auto-hover, for sure--possibly the kind that can be adjusted with some sort of "coolie hat" arrangement on the cyclic. Something is needed that is easy to set, and can enable small corrections without having to reset the whole system. It would be nice if the different axes were independently modifiable, so that you could hold an altitude, and still drift sidewards at 4-5 knots. We discussed some of the problems associated with fly-by-wire and fly-by-light systems, and potential difficulties with pulse radiation. Some committee members felt that having a pure fly-by-wire system linked into a computer with no manual backup was just looking for trouble in a nuclear battlefield--several kinds of pulse radiation are known that can turn chips back into sand.

6. VOICE TECHNOLOGY INTEGRATION

The committee felt that a speech input and output capability needed to be looked at in conjunction with the functional requirements of the mission for 1990's aircraft. Voice input and output is not just a technology by itself that you take off the shelf and brute force into an existing airframe. Current research at NASA-Ames by the Crew Station Integration Group has shown that you need to make the application of this type of technology mission specific. All of the systems that we are presenting to the pilot, both auditory in the form of warning messages, advisories, etc., and visual, need to have some kind declutter mode. We need some kind of mode that you as the pilot could engage, and say to the system "don't tell me anything that I don't need to know right now", or "tell me in the shortest way possible, I'm busy". The particular format of the warning must be pilot selectable. The pilot is the only one who knows what the situtation is at any given time. There are times when the pilot wants all the information that he can get; there are other times when he does not. There are other times when he will not be able to make an adequate decision anyway, because his choices will be very limited. In that case, all he needs is quick input capability. Either system by itself is not what the pilot wants. What he wants is the ability to have either system at his command--not always terse, not always verbose, but having the potential for either.

7. COCKPIT SHOULD INCLUDE NBC PROTECTION. The committee felt that protection for the pilot from nuclear, biological, and chemical (NBC) weapons must be integral to an LHX type cockpit. Current protective clothing is not capable of being worn for long periods of time, particularly while a pilot is flying. A closed cockpit is one alternative, something with some sort of positive overpressure to keep contaminants out. The problem still remains, of course, of how does the pilot get out of the aircraft if the area is contaminated (such as at a refuel or rearm point). Also, taking a hit in this type of cockpit is more critical if your protective capability is now downgraded. How do we decontaminate a helicopter before it comes into a "clean" area?

COMMENT: You also have to realize that there is a danger to some parts of the aircraft from various chemical agents as well as a danger to the pilot. You have huge air intakes that are out there scooping in everything, and blowing it right through your compressor section. A set of finely constructed, thin metal blades that don't take much etching to become out of balance are very vulnerable to the effects of chemical agents.

We have no real answer to the NBC problem, but the questions are numerous and vital, and must be answered.

8. PUBLIC SERVICE SPILLOVER

The last area that we discussed was a concern brought up by a public service helicopter representative of our committee. He stated that most of the public service agencies, such as police, fire, paramedics, and forestry services, rely on acquiring military aircraft from 10 to 15 years old. They use these military surplus aircraft because local budget constraints severely limit the amount of new equipment they can afford. He said that it would be nice if when the military designed and built a helicopter, they also consider the eventual user in the public service sector. He did not expect DOD to design a vehicle for the public service sector, but stated that eventually a single pilot helicopter would be of very limited value to them.

QUESTION: Why can't someone like the police department use a single place rotorcraft for surveillance work?

His answer to that was that that would be fine if a surveillance mission stayed that way the whole time, but typically there is a traffic accident or someone needs to be transported to a hospital. The flexibility of a 3-4 passenger aircraft is essential for most police work.

GENERAL DISCUSSION AND QUESTIONS

QUESTION: Did your committee favor the "Black Box" approach to design of an LHX type of aircraft?

When you have a black box concept with modular replacement, your entire forward maneuver arm is dependent on the black box factory. If you lose your black box factory, you lose your entire fighting force. The alternative is to have everything be fixable with a screwdriver and wrench; but how do you get the personnel that can do that, and how do you train them, and support them in the field?

QUESTION: What did your committee decide, if anything, about workload in general in the helicopter NOE environment?

We all agree that we have got to reduce workload. The question is two fold: What is workload, and what other factors get defined in the general catch-all of workload (such as fatigue)? Then, having defined workload, how do we measure it so that we can tell if our methods have reduced it? If we try to reduce workload by making systems very simple, we might actually be increasing workload because the systems are so simple that the pilot cannot get the information he needs. We could not agree on an answer to this question.

QUESTION: Going back to your earlier comment about the selection process for pilots, why can't we just make the aircraft easy enough to fly so that there is not a selection problem?

You have to design your airframe for the population that will be flying it, it's true. We may have a problem, however, if we degrade our potential airframe performance to the point where the lower third of the flight class can fly it. That works fine until you run up against an enemy who is flying the top third of his flight class in an aircraft that can turn a little faster, or take a little more "G-force", or accelerate a little better, and the pilot is better than yours. You can't degrade aircraft performance to fit pilots who can't fly well.

OPERATIONAL REQUIREMENTS COMMITTEE ISSUES

I. ISSUES WITH AUTOMATION

A. Rules of Priority
B. Pilot as a system manager rather than a technician
C. What do you lose when you automate - Skills?

II. INCREASED COMPLEXITY

A. Training costs become high with increased complexity
B. More complexity requires better pilot selection
C. How transparent should we make complex systems?

III. COCKPIT WORKLOAD HIGHEST IN NAVIGATION

A. Passive navigation system needed
B. Need to be able to input data with electronic media

IV. CREW STATION LIFE SUPPORT DESIGN

A. Critical for long duration missions with single pilot
B. Seat and control arrangement must be optimal
C. Need for sidearm controllers and ECU

V. AUTO HOVER AND FLIGHT TRIM CONTROLS

VI. VOICE TECHNOLOGY IN INTEGRATED FORM

VII. SYSTEMS MUST HAVE VISUAL AND AUDITORY DECLUTTER MODES

VIII. COCKPIT SHOULD BE DESIGNED TO BE NBC RESISTANT

IX. CONSIDERATIONS FOR SPILLOVER TO CIVILIAN PUBLIC SERVICE

N85 14824

AVIONICS TECHNOLOGY – SYSTEM CONCEPTS

By

Mr. J. S. Bull and Mr. R. B. Huntoon

REPORT OF

THE AVIONICS TECHNOLOGY - SYSTEMS CONCEPT COMMITTEE

OBJECTIVES

The first item of open discussion was to review the committee's proposed objectives and insure everyone was clear on the committee's purpose. Committee objectives were established as:

1. Identify Avionics System Concepts research to meet technology needs of advanced helicopter integrated cockpit design.

2. Identify specific avionics system concepts research which should be conducted and/or support by NASA to most effectively aid industry in advanced helicopter integrated cockpit design.

TASKS

The Committee then proceeded with the following series of tasks in order to accomplish committee objectives.

1. Identify candidate Missions and Mission Requirements to be considered.
2. Identify problems/issues which degrade and/or prevent accomplishment of the candidate Missions.
3. Identify research needed to develop technology in the problem areas.
4. Identify what portion of the research should be conducted and/or supported by NASA.

CANDIDATE MISSIONS

The committee discussed the following Missions.

1. Civil Air Transport (Offshore, Corporate, Commuter).
2. Civil emergency medical service.
3. Search and rescue.
4. Special service.
5. Military attack/scout.

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CANDIDATE MISSION REQUIREMENTS

The committee discussed the following Mission Requirements.

1. Single pilot operations.
2. Night operations.
3. All-weather operations.
4. Category IIIc landing operations.
5. Obstacle avoidance.
6. Wire detection.
7. Nap-of-the-earth (NOE).

MISSION REQUIREMENTS RESEARCH FOCUS

In order to establish a research focus, the Committee assigned a low (L), medium (M), or high (H) classification to importance of mission requirements for each of the candidate missions as indicated in the matrix in Table 1 in the Appendix. After discussing the matrix, the Committee determined that the Military Attack/Scout (LHX) Mission requiring Single Pilot, NOE operation under night and all-weather conditions would provide the most demanding set of requirements for a research focus.

SYSTEM CONCEPT

The Committee then discussed basic system concepts which would provide a single pilot, NOE capability under night and all-weather flight conditions. The concepts considered were very similar to those proposed in the current NASA Superaugmented Rotorcraft Program (see Appendix B). The system concept was to blend all available information from various inertial, radio, and imaging sensors through data fusion methodology including optimal state estimation and image processing. Outputs of the data fusion would drive trajectory generation guidance laws which provide inputs to pilot displays and controls. Pilot displays would include both 2D and 3D perspectives, and would operate in both manual and automatic flight control modes. An Integrating Intelligence would be provided so that the pilot could perform in a "system manager" role. The system would have to provide a "natural" environment, so that pilot training requirements would be minimal and pilot workload low.

CANDIDATE PROBLEMS/ISSUES

The following candidate problems/issues were considered and discussed:

1. High pilot workload.
2. Deficiencies in cockpit design procedures for integrated systems.
3. Visual judgement of size, distance, and location with imaging displays.
4. Certification of advanced integration systems.
5. System reliability.
6. System modularity.
7. Poor low airspeed information.
8. Shared versus dedicated displays/controls.
9. Inadequate input/output media (voice, visual, tactile).
10. Inadequate monitoring/warning systems.

CANDIDATE RESEARCH AREAS

The following candidate research areas were considered and discussed:

1. Computer/pilot function allocation.
2. Interactive voice control.
3. Automation requirements.
4. Redundancy management.
5. Fault detection and annunciation.
6. Tactile controls and displays.
7. Cockpit design methodology.
8. Cockpit design evaluation techniques.
9. Digital map navigation requirements.
10. Integrated FLIR and radar imagery.
11. Decision aiding.

12. System architecture.

13. Display symbologies.

MAJOR RESEARCH AREAS FOR BOTH INDUSTRY AND NASA

The following major categories were identified as avionics research which should be conducted in order to meet the technology needs of advanced helicopter cockpit design in the 1990's. These areas would also include NASA participation through either in-house research and/or support under contract to industry. Items 1-5 deal with system functional requirements.

1. System Management

   This area of research involves utilizing the pilot as a "system manager" and requires development of some type of "integrating intelligence" using artificial intelligence capabilities to aid in automated decision making.

2. Level of Automation

   This area of research involves determination of optimal allocation of functional requirements between the pilot and the computer systems in order to fully automate as much as possible for single pilot operations. For example, the fully automated navigation and guidance would allow the pilot under NOE to devote his attention to mission-oriented tasks.

3. System Controls to Reduce Pilot Workload (Pilot inputs to the System)

   Single piloted NOE operations under night/all-weather flight conditions presents a severe environment and significant technological challenge in terms of keeping pilot workload at an acceptable level. Onboard controls which need to be researched to aid in pilot workload reduction include interactive voice, tactile, and visual.

4. Future Display Technology (System outputs to the pilot)

   Display technologies (visual, voice, and tactile) need to be developed. Visual display requirements need to be established in terms of field of view, image resolution, and superimposed guidance symbologies.

5. Data Fusion Methodology

Methodology needs to be developed for blending all available sensor information (radio nav aids, inertial sensors, imaging sensors) onboard the aircraft in a manner that provides the pilot with optimal state estimates of the aircraft and an optimally fused flight guidance image. Studies should be conducted to determine design requirements for automatic navigation capability through terrain correlation with stored digital maps and through scene matching with stored images. Speed and memory requirements of onboard computers need to be established.

6. Cockpit Design Evaluation Methodology

New pilot system models are needed so that greater use can be made of computer analysis to evaluate design considerations and alternatives. Studies should be conducted to determine what evaluation metrics are best suited for analyzing integrated systems. It is too expensive to make guesses and then go through fly-off competitions before appropriate analyses have been made.

7. Simulation Fidelity

How accurately, how real world does the simulation have to be for two purposes, one for training and one for engineering evaluation and design purposes. Studies are needed which will establish simulation fidelity requirements to serve the desired simulation objectives.

MAJOR RESEARCH AREAS FOR INDUSTRY

The following major categories were identified as avionics research which should be conducted by industry to meet the technology needs of advanced helicopter cockpit design in the 1990's. These areas would not include NASA participation.

1. Electronic Warfare Vulnerability

This area deals with attempting to make the helicopter as invulnerable to detection and countermeasures as it can be. Certainly, one potential system design is the use of fiber optics to provide some measure of protection against electronic warfare. The impact of mustard gas should be considered.

2. Sensor Technology

There needs to be development and refinement in the area of sensors in order to provide the pilot with a high fidelity "real world" image of the surrounding environment regardless of his weather conditions. Some extremely fine resolution imaging sensors exist. It is primarily a case of refining existing sensors, rather than new sensor inventions.

3. System Architecture

This area may call for major breakthroughs, at least away from past ways of accomplishing integrated systems. The traditional manner of buying various black boxes and plugging them together for an integrated system will not suffice in the future. It will call for a different attitude on the part of industry and the customer to put a future integrated system together. Each vendor will require closer cooperation with his competitors. All of our research will be meaningless without this cooperation.

CONCLUSION

The Committee concluded that NASA research areas suggested by the Avionics Technology - System Concepts Committee closely coincides with research areas proposed in the NASA Superaugmented Rotorcraft new initiative.

MAN-MACHINE INTERFACE REQUIREMENTS – ADVANCED TECHNOLOGY

By

Dr. R. W. Remington and Dr. E. L. Wiener

REPORT OF

THE MAN-MACHINE INTERFACE REQUIREMENTS

- ADVANCED TECHNOLOGY COMMITTEE

The goals of this workshop were to 1) identify research issues and areas necessary to meet the needs of the rotorcraft community over the next few years; and 2) identify which of these areas NASA should support. The Man-Machine Interface Requirements Committee attempted to meet these goals by defining areas where increased understanding of the human operator and the interaction between the operator and the avionics could lead to improvements in the performance of current and proposed helicopters. These goals required the committee to consider both current and advanced helicopter systems and avionics. Significant changes in helicopter cockpits are likely to occur over the next few years. Thus this committee tended to recommend broad research areas.

The research topics discussed below represent a synthesis of many individual topics that were represented. A simple enumeration of all the topic areas proposed would have produced a very large document with little internal structure. Thus, the committee chairmen took it upon themselves to organize and classify the individual topics into major topical areas. These areas generally reflect the consensus of the committee members. There were topics on which the committee was split over whether research was needed, or what kind of research was needed. Controversial areas were excluded only if the chairmen felt there was a compelling argument for the major research having already been done.

STRUCTURE

Figure 1 shows the topics discussed in committee. The meeting was organized around three technology areas: Artificial Intelligence (AI), Voice Technology, and Visual Displays. The discussion focused on problems that can be anticipated as a result of current technology. AI, voice input and output, and advanced visual displays are technologies that will dominate the man-machine interface for the next decade or more. The implementation of each creates unique problems for the display engineer, and the integration of these technologies into the cockpit is a challenging problem. Our committee attempted to identify research needs that would insure that the implementation of these technologies would increase the capabilities of the human operator. This requirement generated major concern. Integration of the three technologies into the cockpit emerged as an important topic warrenting

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separate discussion. Several miscellaneous topics were also discussed including performance and workload assessment, and nuclear, biological and chemical (NBC) considerations in military helicopter operations.

It became clear as the discussion progressed that more structure was needed. The committee decided to focus on single-seat, nap-of-the-earth helicopter operations as a target objective to guide discussion. The choice is defensible because of its importance, the difficulty it poses for systems designers, and the stress it will place on the human operator. Single-pilot NOE will require advances in all three technology areas, including their implementation. Man-machine interface requirements in the LHX environment will be extreme due to the time critical nature of decisions to be made, and stress imposed on the operator for having to make life and death decisions while attending to a multitude of tasks. The transfer of information between the man and machine must be fast and effortless for the operator. This requirement poses unique challenges for AI, voice, and advanced visual displays technologies.

ARTIFICIAL INTELLIGENCE

Figure 2 shows the research areas in AI that the committee felt were most important. The term artificial intelligence was given a broader meaning than one typically finds. Our committee considered the automation of many functions, whether or not they mirrored human reasoning, or manifest sophisticated, complex decision making processes. Our concern was with the interaction of the man with increasingly intelligent, automated cockpit systems. Future helicopters will undoubtedly include computer augmentation capabilities ranging from low-level automation of flight controls to very complex reasoning reflecting knowledge of mission goals and models of operator capabilities. Our committee considered the full spectrum.

WHERE IS AI APPLICABLE: The identification of candidate cockpit applications for artificial intelligence is one of the most important issues for current research. To this might be added the determination of the kind of artificial intelligence needed for a given set of functions. The ultimate solution is to automate everything and allow the pilot to select if and when the automatic system is to be actuated. But, this is simply not practical for the near future. Emphasis should be placed on the identification of those functions that are most difficult, time-consuming, and pose the highest workload for the pilot. These will not always be the functions which can be easily modeled. For example, navigation is certainly one of the more difficult tasks for the single pilot flying NOE. The co-pilot currently handles navigation, but if the co-pilot is removed, some automation of navigation functions will be necessary. Since navigation involves complex functions, automation will require advances in sensor input, associated control logic and decision rules.

The pilot-system interface is another area where the implementation of artificial intelligence was deemed necessary, but where problems are non-trivial. For example, a single pilot flying NOE in combat will be too busy to deal with much information, aside from that necessary for the control of the aircraft and delivery of weapons. Thus, an on-board system must monitor flight relevant information, assign priorities to messages, and decide what information the pilot needs to know at any given time. Such a dialogue monitoring system would require knowledge of the pilot's capabilities, the mission goals, and the impact of certain information on mission success.

One must anticipate technology in order to identify possible applications. Candidate LHX technology includes advanced symbology, voice and advanced visual displays, sensor fusion, and image processing. These will all require some form of artificial intelligence. Present research can only uncover general principles regarding such information presentation. Other important research issues will emerge as technology becomes better defined.

DECISION AIDING: The committee felt that decision aids would play an increasingly important role in helicopter operations in the near future, and that more research was needed to decide where and how these aids could best be used. As aircraft systems gain greater capabilities to make complex decisions, the initial use of computer augmentation will be to aid the pilot in making decisions by providing more information and, more importantly, synthesizing information to generate hypotheses about current situations. The manner in which decision aiding is presented is very important. Much information is probabilistic; it is not clear how to represent probabilistic inputs. Hence, the representation and use of probabalistic information by the human operator is an area in need of more research; one which NASA can contribute and should support. The representation of probabilistic information is but one aspect of research on pilot modeling. We know little about how pilots will respond to intelligent systems, how to present information that can be understood quickly and easily, or how to structure access to computer data bases so that pilots can quickly access desired information. For example, it is generally not sufficient to recommend a course of action, unless the pilot understands the reasons for it. Understanding the conventions humans use to communicate such information would be of considerable use.

REAL-TIME AI SYSTEMS: Helicopter missions, especially military operations, are seldom so straightforward that all contingencies can be planned in advance, or even in time for a well considered solution. The pilot must be able to interact with on-board intelligent systems in real time. Real-time operation is not a problem for many current and proposed automated systems. However, for knowledge-based, heuristic systems, and decision aiding system, real-time operation is beyond current technology. Even the inclusion of time related knowledge and reasoning would represent an advance over existing systems. It was felt that research toward the representation and use of time related information is necessary.

RELIABILITY: No system is perfect. How will a pilot know when or if an intelligent system is giving faulty information? Pilots understand how dials work, but expert systems are understood by only a few system designers. Such systems often do not perform well when the information does not correspond to that which is expected, but most are not smart enough to know what they don't know. Research into this kind of "metalogic" is important and should be pursued. This will hopefully lead to the design of systems that can monitor their own performance.

Equally important, we must gain a better understanding of how the human operator can detect when information is no longer relable. What effect, for example, does the detection of an error have on the operator's faith in, and use of, a specific system. AI systems must be designed so that errors can be easily detected and the cause determined. This is made more difficult since the human operator will usually have neither the time nor expertise to trace the steps the computer used to reach a decision. Transparant systems or programs that allow the user to step through a decision process to see the information used and how it was weighed to reach a decision, are useful only if sufficient time exists.

IDENTIFICATION OF NEAR-TERM TECHNOLOGIES: A better understanding of what could be expected from knowledge-based systems over the next few years would be valuable for assessing how and where AI could be used. Is it realistic, for example, to expect real-time, knowledge-based systems by the end of the decade? The answer obviously depends on the complexity of the task, but also on new developments in avionics. Sensors and displays are changing, and the functions of AI subsystems must change with them.

COGNITIVE MATCHING: Much has already been said about the need for more adequate pilot models. The structure of intelligent subsystems needs to be matched to the capabilities of the human operator. Data bases, for example, should be designed to be easily and rapidly accessible to pilots. Efforts should be directed at modeling the information processing required of the pilot for each mission segment. Intelligent on-board systems could then anticipate operator requirements. Further, a pilot model might also describe the pilot's representation (schema) of the aircraft and mission. Such a model could facilitate information presentation to the pilot, compatible with his internal representation, thus facilitating his understanding and response to the information.

VISUAL DISPLAYS

Figure 3 shows the areas the committee felt had the greatest pay-off relevant to visual display technology. The technology for visual displays has become increasingly sophisticated. Our understanding of the human has not kept pace with this increased ability. As a consequence we have, or could have, the ability to present information in a variety of ways, if only we knew which ways could best benefit the operator. The major theme, then, for research on visual displays is an increased understanding of the relationship between the kind of information presented and the manner in which to present that information. This relationship encompasses not only the activities of the operator's sensory systems, but the operator's cognitive representation of the system and task, and inevitably the action that needs to be taken.

DISPLAY FORMAT: Issues related to display symbology and the use of color have been researched for many years, yet remain a problem. Uses of color displays in the cockpit are often limited by lighting conditions and expense, or by a lack of knowledge about what information should be conveyed by color. Color may be useful in helping to segment cluttered displays. More work needs to be done in this area.

The choice of symbology for a display should be based on more than tradition or face validity. Research is needed to develop quantitative measures of visual similarity/discriminability for symbology. The choice of symbols should also be dictated by the information to be conveyed and the action needed to be taken by the operator. This means that more effort needs to be directed at identifying the characteristics of displays that make them compatible with the operator's representation of a system and the resultant action that must be taken.

Integrated multifactor displays promise to provide the operator with easy access to a wealth of information by representing the information as states of one or more dimensions of a unified figure. For example, the size of a circular ring could represent height above ground, while distortions of the circle into an ellipse could represent pitch angle. Many such integrated displays have been proposed in the past. The problem is that none are based on an understanding of information representation, nor has any exhaustive comparison of different techniques been undertaken. In fact, the entire area of graphic display of flight information needs to be explored. Not only with regard to specific displays, but with a mind to the development of principles to guide the design of such displays. This is an area where NASA could contribute greatly, and should be active in support of related research.

HELMET MOUNTED DISPLAYS: Helmet mounted displays have been used to display flight control information, to improve night vision, and for weapons system control by head position. Helmet mounted displays could serve multiple purposes in future cockpits like LHX. One of the major problems with such systems is weight. Another problem is slewing rate, and in the case of digital systems, frame rate. As the head is turned, the displays cannot present information at a sufficient rate to keep up with head movement. When the head stops, the display may lag milliseconds behind. Head movements happen frequently, often accompanying eye movements of as little as 5 degrees. Research is needed to assess the potential utility of HMD's and to improve their update rates.

THREE-DIMENSIONAL DISPLAYS: Depth information can provide important cues under the right circumstances. The use of depth cues has been proposed for both the outside scene, and for cockpit displays. There are two basic means of presenting depth information, stereoscopically, and by linear perspective. Normal use of binocular, stereoscopic, depth cues is limited to 15-20 feet from the observer. This can be increased by extending the effective distance between the eyes, by means of special glasses, or by cameras mounted several feet apart. Since our normal use of binocular depth cues is so limited, and our perception of motion and distance tied to normal binocular cues, research is needed to identify the potential benefits of enhanced binocular displays.

Linear perspective provides monocular depth information, and can be used to present depth information on cockpit displays. The use of perspective invariably results in distortion. Conditions under which distortions can and cannot be tolerated, and how distortions affect information transfer are important research issues. More general information relating to the ability to extract distance information, height, etc. from linear perspective displays is also needed. NASA is in a unique position to conduct and support research on such topics. Multi-factor displays are alternatives to the direct representations of depth information. Efforts should be directed to identify applications which require perspective or stereoscopic depth cues, and those that can benefit from multi-factor displays.

SENSOR FUSION: Advanced visual display proposals call for the combination of information from many different sensors. The LHX scene display, for example, might consist of a television camera input of some field-of-view combined with FLIR information and millimeter wavelength radar, all presented on a wide screen display. How is this information to be displayed to the pilot? Should there be visual clues to denote which sensor is registering a given object? The amount of information available with fused displays can produce a very cluttered visual scene. Some means of reducing the information to manageable proportions is necessary. This will require an understanding of the pilot's needs at specific times, which may lead to significant levels of automation.

VISUAL REQUIREMENTS FOR MISSIONS: The committee was unanimous that more needs to be known about visual information required to perform specific missions. NASA should support research on visual cues used in landing, NOE flight, and civil helicopter operations that depend heavily on visual information.

IMAGE QUALITY: This is a traditional concern of visual display designers and is still an important area for research. With the introduction of sensor fusion, integrated displays, alphanumeric CRT displays, and multifunction displays, the demand for image quality is increased. The important research efforts in this area should be directed at quantitative measures of image quality and quantitative models of human perception as it applies to information extraction from CRT displays containing a large number of closely packed symbols.

SYMBOLIC OVERLAYS: Advanced visual display concepts calling for sensor fusion, computer generated map displays, moving map displays, etc., all involve overlaying symbols of threats, friendlies and obstacles on some representation of the visual world. This representation can be an outside scene display, map, adar display, or threat warning display. Superimposed symbology will be very useful in finding targets, identifying scene elements, planning a flight path around obstacles or enemy weapons, or distinguishing between friendly and enemy vehicles. To make the best use of symbolic overlays, intelligent systems should be introduced that can decide what information is needed at different flight stages. The potential number of symbols on a given display is large, and more must be known about how to effectively integrate large classes of information--e.g. friendly vs foe--to facilitate rapid evaluation. Partial information from symbols and displays is usually sufficient. Research on how to design symbols and displays that make certain aspects of that information easily accessible would be valuable.

VOICE TECHNOLOGY

Figure 4 shows the research areas recommended by the committee for both speech recognition and speech synthesis. Speech recognition and speech synthesis systems are being tested for possible implementation in helicopters, as input and output devices. For some functions, voice input and output will be useful to allow the operator to input or receive information without looking away or taking his hands off the primary flight controls. Questions remaining have to do with the use to which systems will be put, and how the characteristics of acoustic messages will interact with human information processing. Speech perception differs fundamentally from visual perception. Likewise, speaking is different than manual responding. These differences will have important consequences upon voice systems. The implementation of voice in the cockpit should depend upon how the operator processes this type of information.

SPEECH RECOGNITION: As with artificial intelligence one of the primary issues in speech recognition is function allocation. Where will it be most useful? The same criteria apply here as for AI. Speech recognition systems will impact pilot workload, but initially on non-critical tasks. This is currently an area of intensive research.

One of the requirements for function allocation will be the sensitivity of the recognition system to changes in the human voice under high "-G" and/or emotional stressors. Some committee members felt that more work needs to be done on how the human voice changes under a variety of in-flight conditions. This concern can be generalized to include other acoustic interference that might affect the recognition system. Other committee members felt that this information could expand the use of speech recognition systems, but was not a problem for the introduction of recognition systems for non-critical tasks.

Speech communication places increased demand on the operator's memory. Pilots are accustomed to standard vocabulary and syntax, and to communicating this way with others. If they forget a word they can substitute something close, or the listener may infer what is meant. Automatic speech recognition systems are not so forgiving. Research should identify the need for flexible vocabulary and syntax, and some form of command language with restricted syntax and vocabulary, or a more natural language input.

One of the potential uses of voice would be to delete unwanted information from cluttered CRT screens. Operators could select desired display components. The desirability of such a capability needs to be established.

Increased memory demands come not only from the need to remember words and word order, but which functions can be accessed by voice and which cannot. This will require that all systems come with manual inputs, or that some memory aids be provided the pilot. The latter maybe preferable, since future cockpits may not have convenient manual inputs for voice functions.

SPEECH PRODUCTION: Voice warning messages are already in use in aircraft. Several proposals call for an increase in the number of systems that can deliver information vocally. While this would relieve the pilot of the necessity of looking at cockpit instruments, it also would increase the load on the auditory channel. The use of synthetic speech, as opposed to digitized human male or female speech, has been suggested for presenting cockpit information. Since the acoustic characteristics of this speech are different from human speech in many ways, the pilot could easily tell that some on-board system was delivering information. Several research efforts are investigating the intelligibility and benefits of synthetic voice.

Simple segmentation may not be sufficient when the number of on-board systems using synthetic speech is large. Each will have to alert the pilot to its identity. One approach might be to use different voice characteristics, much the same way that people can be recognized by voice.

Speech production also places increased demands on human memory when it is used as an information source. Voice messages differ from visual in that voice messages occur unbidden and go away after delivery. Abrupt changes also occur on visual displays, but normally the pilot acquires information by routine scan. Voice displays could also be scanned on request, but this is slower than a visual scan. Interruptions are likely to lead to high stress situations. Also, visual displays continue to register thus the pilot can prioritize for multiple responses. The differences between visual and auditory information will require that some logic be incorporated to prioritize message delivery. Protocol must also be developed to allow the pilot to recover messages that were not heard, responded to, or forgotten.

COCKPIT INTEGRATION

Figure 5 shows the main cockpit integration issues. With cockpit integration we recognize what is really "old time religion", that a cockpit is an ensemble of inter-related devices, not a collection of discrete devices. All too often we fall into the trap of piecemeal/optimization saying, "Let's solve this problem by putting this black box in, let's put in a radar altimeter, now let's put in a voice synthesizer, now we need a speech recognizer", and so it goes. The trouble with this type of designing is that it fragments the problem into a series of sub-optimizations, and never addresses the overall problem of flying the plane and managing its systems (and weapons).

AI may or may not help out. Again, in recommending AI solutions to problems, we must keep in mind the "ensemble", and not view AI as something that can operate on its own without crew supervision and intervention. The committee feels that AI should be used to amplify crew intelligence, not substitute for it. We see AI as useful in carrying out instructions, proposing plans and trial solutions, and not "doing its own thing", as some AI enthusiasts seem to favor. I fear the situation in which AI, operating under its own heuristics (which may be unknown or not clear to the pilot) carries out a plan which may be counter to what the pilot, or the mission, requires. The pilot may feel "Way out. Why didn't I think of that?" Or he may be completely baffled by the AI solutions.

We agree with the remarks of Azad Madni, who emphasized that AI should not be viewed as a black box operating in isolation from the human crew. The important point is to ensure that AI keeps the pilot informed of its potential solutions, and the pilot maintains veto power for anything that is unacceptable.

Speech input offers a convenient interface between the pilot and the AI device. The pilot will be able to set parameters, determine goals, and supervise solutions by voice input. The committee sees a bright future for speech input and output, but believes it is not an overall solution to human-device communication problems, mainly because it is slow, it has a high potential for interference, and it interferes with human-human communication which will be so vital in helicopter warfare in the future. Like automation, speech I/O involves some problems and creates others, and also like automation, it cannot cover up fundamentally bad design.

I am concerned mainly about the time domain of speech I/O. I would like to suggest that the first thing we dispense with is polite dialogue, such as we often see in laboratory demonstrations of some commercially available systems. It may be attractive in a lab or office to have the machine say, "Good morning Mr. Operator, is there anything you would like me to do?" But operating 10 feet off the ground, in and out of trees, and being fired upon, polite discourse would be one of the first things I would be willing to dispense with.

We also raise questions about the keyboard. I have had some critical things to say about the rapid advance of keyboards as the input device of the present and future. If keyboards must be used, then human factors specialists must take the lead in cleaning up human-computer dialogues to minimize not only keystrokes, but error probability. We cannot afford to have pilots going through typing exercises before or during combat missions. In brief, we must find better, faster, and less error-prone ways of getting information into a digital device.

One approach might be something like that employed by Apple in the Lisa computer — a display with icons representing options and commands, and a cursor slewed by a tracking ball or joystick. This, of course, does not meet the hands-off ability of speech input, but does relieve the pilot of keystroke operations, and probably produces fewer input errors.

On the output side we need to reconfigure for the various needs, as the mission changes, or as the phase of the mission changes, or according to what is happening to the helicopter. We may want to declutter, or display pilot options. The soft display allows the pilot to reconfigure his cockpit for his particular need or whatever the mission calls for at any given time. This is not "Blue Sky" technology, for it already exists in the 767 where the same tube can be used to display a compass rose, a map display or a traditional HSI. (Question) It's going to have to come in through some link whether the sensor itself is onboard or not. It's possible that sensor is going to be another aircraft or it may be a satelite or something like that? (Wiener) We don't care where the information comes from: It's what do you do once you get it inside the cockpit. You cannot have a computer driven scope here, and a TV scope here, and something else over here. We have to think about integrating these displays, depending on what's coming and the priority that the pilot wants to attach to each one. The perceived reliability of each device may change those priorities. The pilot's not going to get very many second chances in combat. If he gets out there in clear view of somebody who can take a shot at him, that may be the end of it right there. A helicopter isn't a B-17 that can sit out there and take punishment all day long. That's why he needs an integrated display. The pilot must be provided with one integrated display, and this will require considerable research on computer produced symbology, to make the intra-cockpit world compatible with information coming in from the outside.

As for workload measures, it's all been said before. We need better workload measures, we need to be able to deal not only with observable workload, the kind of thing you can see with the camera or TV or watching the operator, but also to consider mental workload: the important areas of planning, problem solving, mentally trying out solutions, etc. We must be sure that the automation has not increased the workload, especially at critical times, and to ensure that the AI is doing what it is supposed to do, relieving the human of having to use his reasoning ability rather then leaving him out there wondering what the AI is up to.

Closely related to that is the performance measurement issue. A number of people on the committee said forget about workload, we're not going to worry about the workload, what we want to do is know can the machine do the job? Can the man-machine ensemble do the job? Is the system going to perform and if the man is over-worked and the system is performing, don't worry about workload that's a kind of sub-optimization to cut down on the workload. This brings up the question of system performance versus human performance, and our inability to be able to quanify exactly whether the system is performing it's job. The performance measurement question is made more difficult by the wide variety of missions planned for the LHX and other advanced helicopters. A series of performance measures is needed for each one of those potential missions. NBC operations have been mentioned by everyone today, the necessity of working in that type of environment and hampering the operator, either by protective clothing or by building a protective shell around him, is one that is going to be critical in the design of an LHX.

MISCELLANEOUS ISSUES

Figure 6 shows some miscellaneous areas that the committee felt were important research areas. The development of appropriate workload and performance measures continues to be an area of concern. All of the technologies discussed were meant to reduce workload and/or improve performance. The validation of any implementation and the assessment of alternate methods of information presentation depend on adequate measurement For military operations, an understanding of hostile environments, especially the NBC environment, was deemed an important issue. Human factors issues were not clear, but the environment is so destructive to metals and electronics that implications for major system failures on performance must also be investigated.

ORGANIZATION

- ARTIFICIAL INTELLIGENCE
- VISUAL DISPLAYS
- VOICE TECHNOLOGY
- PERFORMANCE ASSESSMENT
- MISCELLANEOUS

FIG. 1

ARTIFICIAL INTELLIGENCE

- WHERE IS AI APPLICABLE

  IDENTIFICATION OF CANDIDATE APPLICATIONS FOR AI

- DECISION AIDING
- REAL TIME AI SYSTEMS
- RELIABILITY OF INFORMATION AND ITS INTERACTION WITH HUMAN INFORMATION PROCESSING

  PILOT MODEL
  PLANNING

- IDENTIFICATION OF NEAR TERM TECHNOLOGIES
- COGNITIVE MATCHING

FIG. 2

VISUAL DISPLAYS

- DISPLAY FORMAT
  - SYMBOLOGY
  - COLOR
  - COMPATIBILITY
  - INTEGRATED MULTIFACTOR DISPLAYS
  - GRAPHICS
- HELMET MOUNTED DISPLAYS
  - PHYSICAL EFFECTS
  - SLEWING RATE
- 3-D
  - STEREOSCOPIC
  - PERSPECTIVE
- SENSOR FUSION
- WHAT ARE VISUAL REQUIREMENTS FOR MISSIONS
- IMAGE QUALITY
- SYMBOLIC OVERLAYS

FIG. 3

VOICE TECHNOLOGY

- o SPEECH RECOGNITION
  - WHERE IS IT APPLICABLE
  - VOICE CHANGES
  - FLEXIBLE VOCABULARY AND SYNTAX
  - COMMAND vs. NATURAL LANGUAGE
  - VOICE TO SELECT DISPLAY COMPONENTS
  - HUMAN MEMORY DEMANDS
- SPEECH PRODUCTION
  - VOICE TYPES
  - VARIETIES OF VOICES
  - HUMAN MEMORY DEMANDS AND THE IMPLICATION FOR SYSTEMS DEMANDS

FIG. 4

COCKPIT INTEGRATION

- INTERFACING SPEECH WITH AI
- INTERFACING VISUAL DISPLAYS WITH AI
- DISPLAY INTEGRATION
- DIALOG PROTOCOLS

FIG. 5

MISCELLANEOUS ISSUES

- PERFORMANCE MEASURES
- WORKLOAD MEASURES
- NBC OPERATIONS

FIG. 6

APPENDICES

APPENDIX A

OPERATIONAL REQUIREMENTS COMMITTEE

CHAIRMAN: DR. J. W. VOORHEES, Ph.D.

CO-CHAIRMAN: DR. H. L. SNYDER, Ph.D.

OPERATIONAL REQUIREMENTS COMMITTEE

Chairperson: CAPT. James W. Voorhees, U.S. Army

Co-Chairperson: Dr. Harry L. Snyder, Ph.D.

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ATTACK HELICOPTER (AH-1T) COCKPIT SYSTEMS INTEGRATION

VIRGIL A. GRAF, Ph. D.
HUMAN FACTORS AND COCKPIT ARRANGEMENT

BELL HELICOPTER TEXTRON INC.

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INTRODUCTION

This discussion summarizes the effort conducted by the BHTI Human Factors and Cockpit Arrangement group for a study and design of the integration of a cockpit control system for the AH-1T (TOW).

The resulting design is a culmination of studies that have been conducted using the existing configuration as a baseline and complementing it with new equipment and subsystems that fulfill the attack helicopter requirements for the foreseeable future. Of primary concern was the requirement to add a missile control system, with secondary considerations for improved NOE and night operations. In addition, growth capabilities for improved target acquisition, weapons delivery, and precise navigation was considered. Along with the addition of new equipment, the aircraft was assumed to have a central multiplex data bus system for information transfer throughout the aircraft and its subsystems.

When adding a new weapon system to an attack helicopter, it is often easy to find a "piece of real estate" for the necessary controls and switches. As past experience has shown, in many cases, a new system can be added which improves the machine capabilities but degrades the crew capabilities by increasing workload. Many times technology is applied to a system for the sake of technology. However, when any change from existing AH-1T cockpits was incorporated into the new integrated cockpit crew workload reduction was a major consideration. The typical AH-1 mission requires accurate armament delivery to a point target while flying NOE in a hostile area which demands peak efficiency from the pilot and the gunner. The addition of a redundant caution, warning and advisory system plus complete status monitoring for the gunner coupled with "hands-on" communication control are a few of the technological additions to the AH-1 which reduces or more evenly distributes crew workload. Replacement of the pilot steering indicator and reflex sight with a full function HUD, in addition to providing gunner access to the Stores Control panel functions, allows the pilot more "head out" time when flying NOE.

From the outset, the new cockpit design concept was aimed at providing the best technical approach to allow flexibility, efficient stores management, reliability and growth potential. The integrated cockpit approach, as described in the succeeding sections, maximizes the use of programmable integrated displays, computer-aided, on-demand information presentation, and digital multiplex information transfer techniques.

The control/display functions described here represent the best approach currently available for upgrading the existing AH-1T (TOW) into an efficient weapons platform. A prime consideration in this design study was to permit improvement of the AH-1T (TOW) through a low risk, building block approach that will provide the user with an effective and affordable attack helicopter.

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CREW STATIONS

BHTI Human Factors Engineering group conducted a study of the AH-1T mission requirements and developed a design which incorporates a low risk implementation approach for the cockpit displays and controls. This approach provides state-of-the-art technology, is simple to operate, is flexible in design, and achieves minimum crew workload through efficient man/machine interface design. A major influence on the cockpit design was the many controls and displays which are required to operate the mission equipment in the AH-1T combined with the limited equipment space available. Test and analysis have shown that the increased workload associated with the operation of all the required systems (as individual components) is excessive, particularly in the already high workload in the nap-of-the-earch (NOE) mission. Faced with these factors, BHTI conducted a series of equipment integration trade studies to examine how the cockpit should be configured to meet the demands of the AH-1T mission. These trade studies formed the basis for the definition of the integrated controls and displays.

From these studies it was concluded that mature technology was available to dramatically improve the AH-1T helicopter cockpits and subsystem controls. Use of integrated and programmable displays, with computer-aided on-demand information, combined with multiple information transfer, are the technological tools that will enable the AH-1T to meet the requirements of the various missions, and enhance flight safety through careful attention to crew workload while providing accommodations for future growth.

Figures 1 through 4 are inserted for a comparison of the integrated AH-1T (TOW) pilot and gunner stations and the existing AH-1T (TOW).

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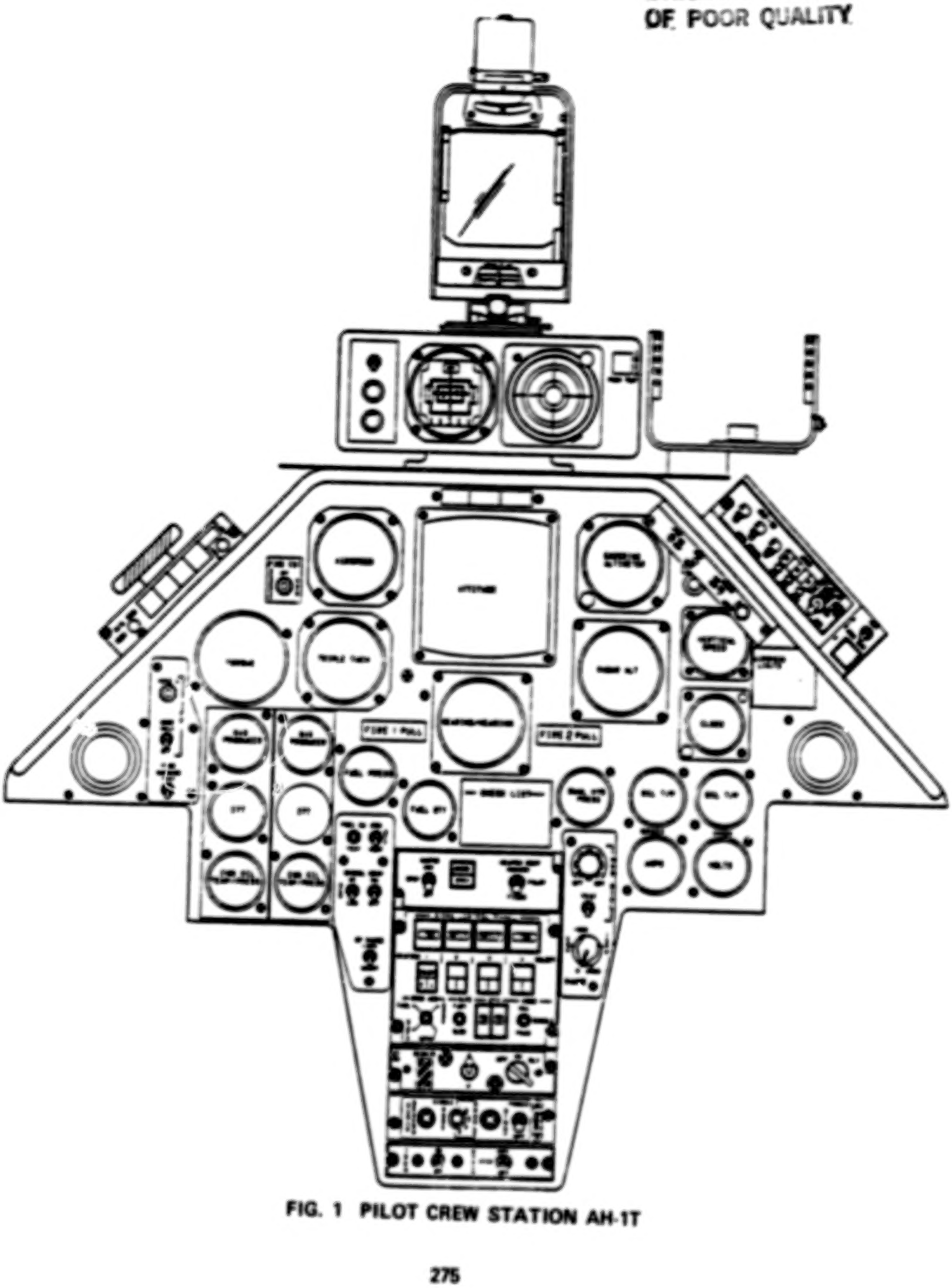
TORQUE
TRIPLE TACH
FIRE 1 PULL
FIRE 2 PULL

FIG. 1 PILOT CREW STATION AH-1T

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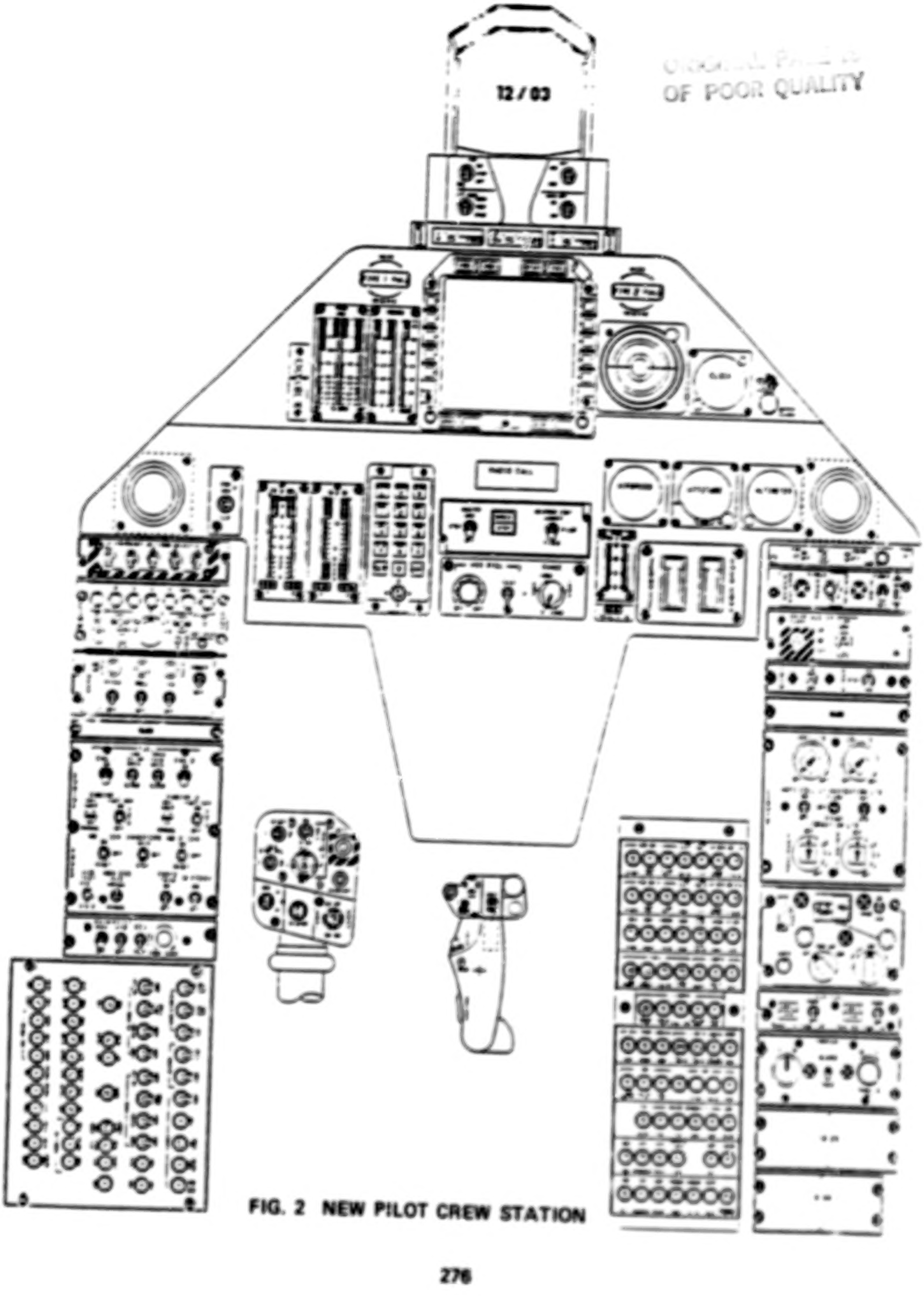

FIG. 2 NEW PILOT CREW STATION